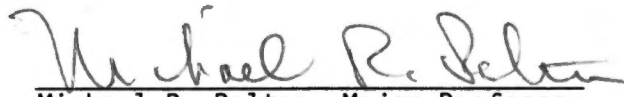
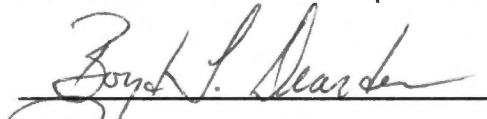


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I am submitting herewith a thesis written by Ben G. Nottingham, Jr. entitled "Raccoon Population Parameters on the Chuck Swan Wildlife Management Area with an Evaluation of Scent-Stations for Monitoring Raccoon Populations in East Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.


Michael R. Pelton, Major Professor

We have read this thesis
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RACCOON POPULATION PARAMETERS ON THE CHUCK SWAN WILDLIFE
MANAGEMENT AREA WITH AN EVALUATION OF SCENT-STATIONS
FOR MONITORING RACCOON POPULATIONS IN
EAST TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Ben G. Nottingham, Jr.

June 1985

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Thesis

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ABSTRACT

The relationship between population estimates and scent-station visitation rates of raccoons was studied on the Chuck Swan Wildlife Management Area in Tennessee. Field work was conducted from 30 July 1981 to 3 July 1983.

In 8,000 trapnights, 248 raccoons were captured a total of 649 times. Capture success of raccoons was significantly different between months ($P < .0001$). Capture success was 9.1% in the first year of the study and 14.8% in the second, corresponding to increases in population estimates. An observed sex ratio of 121 males per 100 females did not differ significantly from 1:1 ($P = .07$). Juvenile raccoons comprised approximately 23% of the capture sample in both years. Fifteen cases of raccoon mortality were documented. Survival rates were lowest in spring and fall reflecting losses due to both emigration and mortality; this complicates assessment of mortality effects even when ancillary information is available. In 1982, breeding activity of adult raccoons peaked in April with most parturition occurring from mid-May to mid-June.

Seasonal estimates of raccoon population size were calculated for 2 study areas on Chuck Swan. Population estimates in 1983 were 25% and 38% greater than in 1982 on the control and experimental areas, respectively. Both open and closed estimators indicated that the raccoon population on the control area was denser than that of the experimental area. The Jackknife estimator in the computer program CAPTURE provided summer estimates of 148 and 120 raccoons

for the control and experimental areas, respectively, compared to Jolly-Seber estimates of 119 and 76. Jackknife estimates were robust and helped assess the negative bias in Jolly-Seber estimates.

Eighteen scent-station surveys were completed over the 2-year study. Mean monthly visitation rate of raccoons for both areas combined was 5.25%. Visitation rates for both areas combined ranged from 7.5% in summer to 2.6% in winter. Visitation rates did not differ among lines ($P=.07$). Visitation rates by raccoons on the control and experimental areas did not differ between years ($P=.12$, $P=.20$, respectively) and among seasons ($P=.27$, $P=.88$, respectively). With the exception of minimum temperature, weather variables exhibited no effect on raccoon visitation rates. Raccoon visitation rates did not vary by overstory type ($P=.21$), the presence of forest overstory ($P=.23$), understory type ($P=.93$), topographic location ($P=.34$), and the distribution of water at scent-stations ($P=.81$).

No significant relationship was found between population estimates and seasonal visitation rates ($P=.78$) or between capture success and visitation rates by raccoons ($P=.44$). Management applications of the scent-station technique, as employed in this study, appear limited because low visitation rates precluded statistical detection of population fluctuations. If the scent-station method is further developed for use in mountain habitat, efforts should focus on increasing visitation rates by designing the technique more specifically for raccoons.

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CHAPTER I

INTRODUCTION

Raccoon (Procyon lotor) management in East Tennessee has become increasingly difficult because of various ecological, economic, social, and political factors. Increased hunting pressure, controversy over equitable consumptive use of the resource and private acts of various counties have contributed to the dilemma of the Tennessee Wildlife Resources Agency (TWRA) in developing a sound raccoon management program (Minser and Pelton 1982). Determining the status and trends of furbearer populations is basic to developing management plans, making decisions on harvest, and promoting public relations (Clark and Andrews 1982). Yet current techniques (bag checks) for monitoring raccoon populations in Tennessee are subject to confounding factors that can bias management information (Nottingham et al. 1982). The scent-station method is emerging as an important tool in furbearer management. However, further evaluation of the reliability of this technique is needed (Johnson and Pelton 1981).

Wildlife professionals face inherent difficulties in obtaining accurate population data on wildlife. Varying activity patterns, secretive behaviors, occupation of inaccessible areas and high mobility present problems in gathering data on some mammals (Lewis 1970, Pelton and Marcum 1977). These problems are compounded by limited financial resources and restrictions on size of the sample area (Linhart and Knowlton 1975). Due to the above reasons, it

is often difficult to obtain reliable density estimates for mammals. As a result, wildlife agencies often resort to indices of relative abundance.

Indirect sign, harvest data, and direct observations are often used as indices of population abundance. Like population estimators (i.e., mark-recapture techniques), indices are subject to sampling error which can be evaluated statistically for assessing precision (Eberhardt 1978). Wildlife managers often find indices advantageous because they are cost efficient and may provide reasonably precise data. However, wildlife managers often assume that indices are directly related to population abundance; this assumption should be verified to allow for the valid use of the technique.

Use of the scent-station method was initially adopted in the western U.S. After examining prospective techniques, the U.S. Fish and Wildlife Service began annual scent-station surveys in 1972 to monitor mammalian carnivores (Linhart and Knowlton 1975). This method was considered the best for indexing the relative abundance of coyote (Canis latrans) populations based on the technique's uniformity, economy, and use over large areas. Although primarily focused on coyotes, the technique provided data for assessing trend and distributional characteristics of 20 carnivore species in 20 western states (Linhart and Knowlton 1975). Refinements in this technique have been made to improve data analysis and field operations (Roughton 1979, Roughton and Sweeny 1982). Despite improvements, Roughton and Sweeny (1982) cautioned users that the method was not a perfected tool and cited its limitations in reflecting density.

In recent years southern states have increased the use of scent-stations for assessing relative abundance of furbearers (Johnson and Pelton 1981, Linscombe et al. 1983). Surveys originally concerned bobcats (Felis rufus) and were initiated to obtain management information (Brady 1979, Hon 1979). Sumner and Hill (1980) evaluated scent-station indices for determining relative abundance of various furbearers across physiographic regions in Alabama. A similar 5-year study in Louisiana evaluated scent-stations as indicators of bobcat abundance based on indices from different geographic regions and habitats; results indicated the method could be employed to index bobcat, foxes (Vulpes vulpes and Urocyon cinereoargenteus) and coyote populations (Linscombe et al. 1983). Leberg et al. (1983) reported that scent-station indices provided favorable results for measuring opossum (Didelphis virginiana) population trends in western Tennessee.

Despite increased use of scent-stations, research has not clarified relationships between population abundance and visitation response (Johnson and Pelton 1981, Clark and Andrews 1982, Conner et al. 1983). Conner et al. (1983) reported that the scent-station technique accurately reflected trends in abundance of bobcats, raccoons, and gray foxes but failed to provide trend data from density estimates needed to substantiate the method as being accurate. Linscombe et al. (1983) suggested that scent-station response provided a valuable index to population abundance of bobcat, fox, and coyotes. However, abundance measures used to compare to scent-station data were drawn from harvest data and literature citations; this precluded precise calibration of indices with population estimates. From the above

discussion it is apparent that the validity of the scent-station method should be established by directly comparing indices with population estimates that establish a population trend.

The purpose of this study was to evaluate scent-station surveys as indicators of population abundance of raccoons in East Tennessee. This study was conducted as one segment in a three-part evaluation of using scent-stations to monitor raccoons in Tennessee. Evaluation of the technique in West Tennessee was made by researchers at Memphis State University, and personnel at Tennessee Technological University investigated the use of the method in middle Tennessee.

A direct approach of assessing the technique requires concurrent monitoring of raccoon population size and conducting scent-station surveys. The following objectives were established: (1) to periodically estimate population size of raccoons from mark-recapture techniques for 2 areas on CSWMA, (2) to evaluate the relationship of visitation rates from scent-stations to population size and other measures of abundance obtained from live-trapping.

CHAPTER II

STUDY AREA

Study Area Description

The Chuck Swan Wildlife Management Area and State Forest (CSWMA) is located on the Union and Campbell County line approximately 40 km north of Knoxville, Tennessee. The area consists of a 9872 ha peninsula surrounded by Norris Reservoir which was formed by the damming of the Clinch and Powell Rivers. The combined study areas encompassed approximately 5133 hectares of the total management area.

CSWMA lies within the Great Valley of East Tennessee which is a part of the Ridge and Valley Province of the Appalachians (Fenneman 1938). This area is characterized by numerous elongated ridges and intervening valleys; valleys range from rolling to hilly and ridges are steep to hilly. Oriented in a northeast to southwest direction, a main central ridge bisects the study area; smaller spur ridges extend from this ridge at right angles. Elevation ranges from 305 m at Norris Reservoir to 512 m at Weaver's Knob. Ridges are underlain by resistant sandstones and shales whereas the valleys are underlain by easily eroded soft shales and clayey limestone (Summers 1968). Frequent dolomitic limestone outcrops occur on lower elevation hillsides and have given rise to sinkholes and caves. Eight caves have been documented and mapped on CSWMA and many others likely exist as evidenced by the author discovering 2 minor caves during this study.

Soils and their drainage patterns have been derived largely from limestone, dolomite, and shale parent material (Minckler 1946). Soils vary spatially due to abrupt changes in these rock strata. Minckler (1946) determined six soil series across the Central Peninsula with Fullerton and Clarksville cherty silt loams covering most of the area. Most upland soils are highly leached, acid in content, and low in fertility. Drainage in the area is rapid and largely due to quick subterranean drainage in lowland limestone strata. In uplands, water is not retained well because of steep slopes and porous topsoil (Rothacher 1953). Three perennial surface streams occur within the study area; most surface streams are only temporary and are practically nonexistent in the fall.

Climate of the area is temperate and continental. Data collected from White Hollow, CSWMA over a 15-year period indicated 117.4 cm of mean annual precipitation (Summers 1968). Most precipitation occurred during winter and midsummer when summer rainstorms predominated. Early spring and late summer/early fall generally produced less rain. Weather data obtained over 28 years in Union County showed an average growing season of 174 days (Minckler 1946). Mean temperature is 3.3°C in winter and 23.8°C in summer (Rothacher 1953). Snowfall occurs infrequently and remains on the ground for only a few days.

Differences in forest cover at CSWMA are a result of both human and biological influences. Minckler (1946) reported that forest differences were related to slope, exposure, and steepness of the Chuck Swan topography. On northerly slopes, oak-hickory

(Quercus spp.-Carya spp.) and yellow poplar (Liriodendron tulipifera) and yellow poplar-shortleaf pine (Pinus echinata) complexes are found, whereas southerly slopes support oak, oak-pine, or oak-hickory associations. Bottomland forests display the highest species diversity with hardwoods such as American beech (Fagus grandifolia), maple (Acer spp.), sycamore (Platanus occidentalis), and yellow poplar being the most frequent. From 1973-1976, a large portion of the southern pine forest at CSWMA was devastated by the southern pine beetle (Dendroctonus frontalis). This occurrence changed the forest composition considerably and favored hardwood regeneration. In addition, the forest diversity appears as a mosaic of various successional stages because of past and present logging and farming activity in the area. At present, at least 93% of the study area is forested, of which roughly 85% is hardwoods and 15% is softwoods (D. Audley, Division of Forestry, Department of Conservation, pers. comm.).

Human development of the Chuck Swan area has occurred for over 200 years. The earliest permanent development occurred in the late 1770's or early 1780's in the Clinch River basin (Safley 1974). Farming primarily of corn and wheat and livestock provided subsistence living but settlement was sparse as only the best farmland was occupied (Summers 1968). Old remnants of buildings, cisterns, former roads, and cemeteries are located throughout the area. In 1935 and 1936, the Tennessee Valley Authority (TVA) purchased land between the Powell and Clinch Rivers to compliment its development of Norris Dam. In 1952, TVA transferred this land to the State of Tennessee for the integrated development of the area's forest and wildlife resources.

Forest resource management of Chuck Swan is assigned to the Division of Forestry in the Department of Conservation. Early management activity was characterized by a lack of long term planning, infrequent hardwood timbering and planting of experimental pine plots. Recent management incorporates long term planning with a strategy of even-aged management for hardwood and pine (D. Audley, pers. comm.). Hardwood regeneration is favored in reforestation. Planning and development are prescribed on a compartment basis with 18 compartments comprising the total area. Besides timber management, the Division of Forestry maintains developed roads on CSWMA which total 144 km.

The Tennessee Wildlife Resources Agency (TWRA) administers and manages the area for its wildlife resources. Management emphasis concentrates primarily on whitetail deer (Odocoileus virginianus) and wild turkey (Meleagris gallopavo); controlled hunts play an important role in population management of these species. Some small game management such as food plot and cropland production benefit cottontail rabbits (Sylvilagus floridanus), mourning doves (Zenaidura macroura), and raccoons. Since the late sixties, agreements with area farmers have augmented big and small game by incorporating agricultural leasing of hay fields and croplands (Safley 1974). Croplands include corn and a combination of clover (Trifolium spp.) and orchardgrass. These crops are planted on a 2-3 year rotational basis (P. Bledsoe, TWRA, pers. comm.). Hay fields and croplands comprise approximately 7% of CSWMA and contribute to roughly 112 km of undeveloped roads leading to these sites from developed roads.

Harvest management of the CSWMA raccoon population has lacked continuity. In the early 1950's managed hunts began and continued until 1965 when the population had declined, possibly from overharvest (Safley 1974). Following a 6 year closure, hunting was permitted from 1971 to 1978 when another closure was prompted due to an apparent overharvest (Nottingham et al. 1982). No trapping of raccoons or other furbearers has been allowed on CSWMA.

Study Area Choice

Estimates of raccoon density and visitation rates of raccoons to scent-stations were measured on 2 areas in CSWMA. The area northeast of the main road was established as a control area; the adjoining area to the southeast of the main road was designated as an experimental area (Figure 1). This design allowed baseline monitoring of 2 areas that will permit assessment of the effects of a planned raccoon hunt in a follow-up study. No hunting was conducted during this study. Logistical considerations of conducting trapping and scent-station surveys necessitated using adjacent areas. It was hoped that a dividing ridge between the areas would act to minimize raccoon movement between areas (Butterfield 1944). Also, the 2 areas were comparable in size (control = 2588 ha; experimental = 2545 ha) and access, and were similar ecologically.

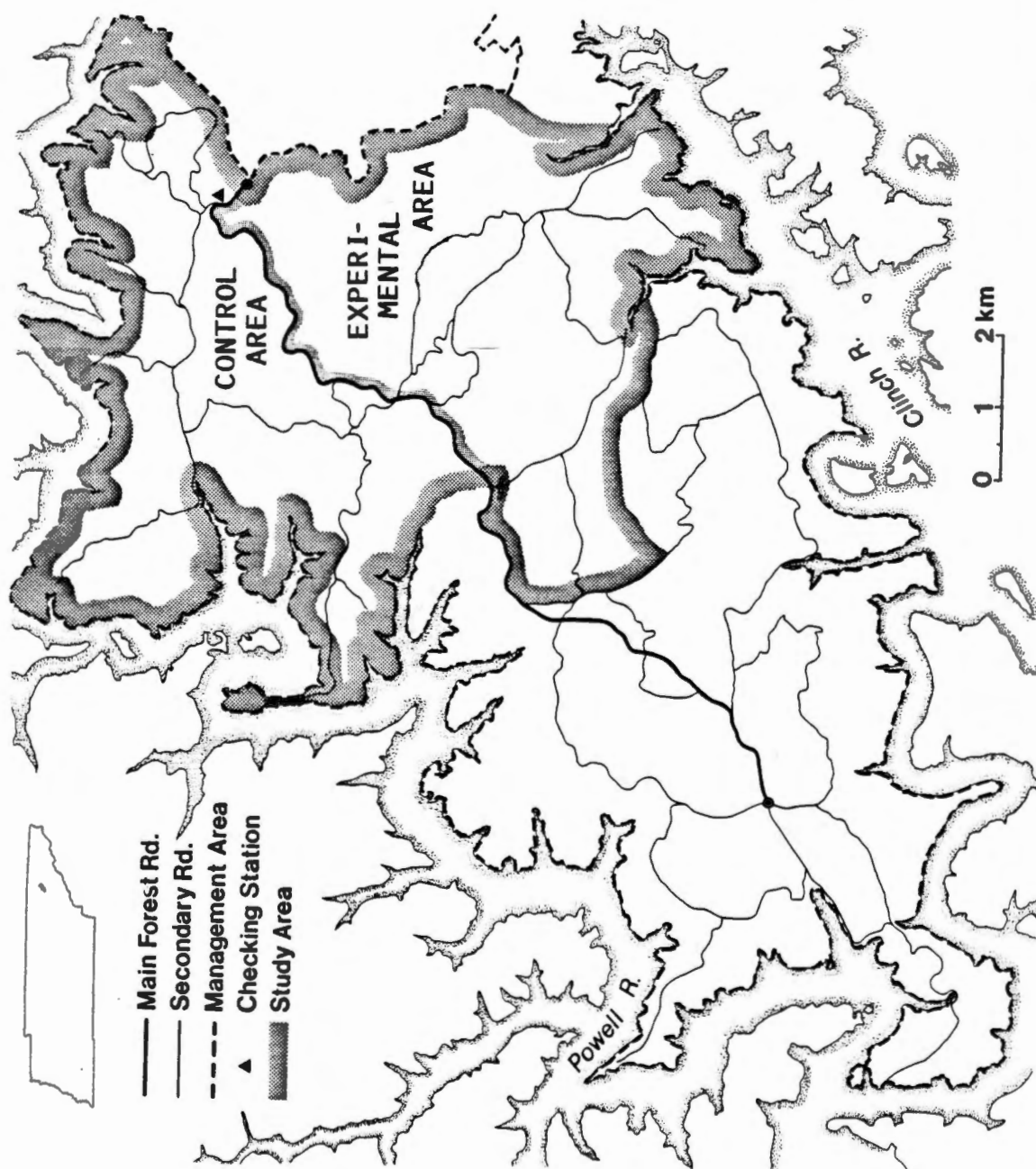


Figure 1. Map of the two study areas on the Chuck Swan Wildlife Management Area, Tennessee.

CHAPTER III

MATERIALS AND METHODS

Population Characteristics

Data collection. Trap sites were located in 0.8 km (0.5 mi) circular quadrats uniformly distributed throughout the 2 areas. Quadrat radius was based on an estimated home range size of adult male and female raccoons from East Tennessee (Hardy 1979) and was less than the average linear distance traveled by raccoons between captures at CSWMA in 1976 (Woods 1978). To position traps in the field, trap sites were marked on topographic maps with the exact location being the quadrat center; access influenced final positioning of traps on or near the quadrat center.

Once established, a trap site was operated for 20 different nights. Initially traps (n=40) were operated in each area separately until completion of the first 20-night period. After the initial 20-night period in each area, it was realized time lags in sampling each area did occur making seasonal population comparisons between areas difficult. The trapping schedule was changed to 20 traps in each area with only half of each area being sampled for 20 different nights. The traps were switched to the remaining halves to complete coverage of the whole study area. Traps were relocated to original sites in each sample period. Using this procedure (sample periods 2, 3, and 4), complete sampling of both areas was generally completed in 3 months.

In 1983, the sampling routine was changed back to the initial format. This alteration was considered necessary after analysis of 1981-82 trapping data indicated that few model assumptions would be violated (discussed later). Improved planning and increased experience in 1983 minimized time lags occurring from different sampling periods between areas.

From 30 July 1981 to 3 July 1983, raccoons and other incidental animals were captured in wire livetraps (Tomahawk Live Trap Co., Tomahawk, WI), baited with sardines. Packing oil from the sardines was spread on small trees near traps and at trap entrances to improve scent dispersal and trapping response. Sticks and rocks were placed around baited ends of traps to prevent bait thefts by animals. Traps were checked daily and rebaited if necessary. Traplines were run in a pick-up truck or more commonly on a Honda CT90 trailbike.

Raccoons and foxes were sedated with ketamine hydrochloride (Bristol-Myers Co., Syracuse, NY) at a dosage rate of 0.2 cc/kg of estimated body weight (Bigler and Hoff 1974). Ketamine was injected through a needle and syringe mounted on a metal jab stick. Immobilized animals were sexed, weighed, and standard morphological measures taken. Raccoons and foxes were ear-tagged with 2 sequentially numbered color rototags (NASCO, Ft. Atkinson, WI). Males received red tags, and females received yellow tags. Animals were examined for general body condition, ectoparasites, reproductive condition, and age. Ages for foxes and raccoons were estimated from tooth wear. Raccoon age was determined using criteria provided by Grau et al. (1970)

which divided raccoons into 5 relative age groups: 0-14 months, class 1; 15-38 months, class 2; 39-57 months, class 3; 58-86 months, class 4, and class 5 (over 86 months). Although Grau et al. (1970) found some overlap in using this technique, the method was determined to be 82.7% accurate in a known sample. Ages of preweaned raccoons were estimated by the eruption of deciduous and permanent teeth; this method permitted precise aging for raccoons up to 111 days old (Montgomery 1964). Random samples of raccoon hair were removed with scissors from the nape of the neck and placed in plastic bags for future heavy metal analysis. Blood samples were drawn from raccoons and foxes in response to reports that foxes were exhibiting abnormal behavior and canine distemper was documented in a captured raccoon on CSWMA. Samples were taken from random individuals and selected raccoons that appeared unhealthy and diseased. Approximately 1 cc. of blood was taken from either the cephalic or femoral veins, then placed in an untreated blood tube. Recaptured animals were identified and released without handling if identification tags were legible and intact. All captured animals were released at capture sites.

Data from newly-captured animals and information documenting recaptured raccoons and foxes were recorded onto field capture sheets utilizing a computer format. This format provided efficient data entry when computer data files were created.

Minimum and maximum temperatures of each trapping day were recorded from a thermometer located at the Chuck Swan checking

station. Overnight weather conditions (overcast, fog, clear) and the occurrence of rainfall were also recorded for each trapping date.

Blood analysis. Blood collected in the field was allowed to clot and samples were refrigerated. Packed in ice, blood was brought into the Clinical Pathobiology Laboratory of the UT Veterinary Hospital within 3 days of collection. Blood was centrifuged at 1500 rpm for approximately 10 minutes. After centrifuging, clots were removed and the remaining sera were frozen until assays could be performed. Blood samples were tested for antibodies of several wildlife diseases including canine distemper virus, parvovirus, and rabies virus. The indirect antibodies test (Hsiung 1973) provided the basis for ascertaining the presence of antibodies. Antibody titers were tested at various dilution ratios ranging from 1:10 to 1:20.

Data analysis. Data files of raccoon capture and trapping activity were created, edited and stored on the DECsystem-10 (DEC) computer at the UT Computing Center (UTCC). Files were accessed and manipulated by the Statistical Analysis System (SAS) (SAS 1979) which was invoked through the DEC-IBM computer interface at UTCC. SAS was utilized to edit, compile, subset, summarize, and perform statistical analysis on capture data. Chi-square tests were conducted on raccoon sex ratios for determining goodness-of-fit to a 1:1 ratio. Factorial designs of a least-squares analysis of variance (ANOVA)

were run to test the effects of month and year on the capture success of raccoons.

Raw capture data for raccoons were used to calculate a capture success proportion that served as a measure of abundance. A formula adjusted for the decreased efficiency of traps sprung by any source provided a more appropriate measure of animal abundance (Nelson and Clark 1973). The benefit of this method was to improve the accuracy of the capture success measure as an indicator of animal abundance (Nelson and Clark 1973). The adjusted proportion was calculated as follows:

$$CE = \frac{A \times 100}{(TU - IS/2)} , \text{ where}$$

CE = catch per effort presented as a percentage, A = number of animals trapped of the target species, TU = number of trap units, I = length of trapping interval (always 1 night), and S = total number of traps sprung by all causes.

Proper design of capture-recapture studies necessitates that researchers make appropriate selection of population models. Model selection should revolve around satisfying as many assumptions as possible because this selection determines the model providing the most robust results. Despite being a long-term experiment, both open and closed models were utilized in this study. Closed estimators were applied to short-term data conforming to model assumptions. Pollock's (1982) approach of analyzing appropriate data in both closed and open models was adopted to provide comparative estimates for evaluating model robustness. This approach was justified considering

Moore's (1983) findings that estimates of raccoon populations can deviate by a factor of 2 or more if appropriate estimators are not chosen.

Population estimates and other vital statistics of raccoons were derived from mark-recapture frequency data. The Jolly-Seber (J-S) model (Jolly 1965, Seber 1965) was selected for population estimation because design of this study likely satisfied most of this model's assumptions. POPAN-2 (Arnason and Baniuk 1980), a computer program which employs a range of variations of the Jolly-Seber model was used to calculate open-population estimates. The full J-S model was used to calculate estimates of population size and associated variance; this model allowed for immigration, emigration, recruitment, and mortality over a sampling period (20 independent nights). The model assumed that capture probabilities varied only by night; however, heterogeneity and behavioral bias in the capture history of raccoons were not allowed in the model assumptions.

The full J-S model in POPAN also calculated survival rates with appropriate variance estimates (Jolly 1965, Seber 1965). Differences in sampling periods of survival estimates were standardized by weighting estimates on a consistent period. Standard errors of weighted survival estimates were calculated by the delta method (Seber 1982:7-9). Comparisons of survival estimates for the two areas were made using the following test statistic:

$$z = \frac{S - S_1}{\sqrt{\text{Var}(S) + \text{Var}(S_1)}}$$

The above test statistic was also used for testing differences between seasonal population estimates within study areas.

Data used in the J-S model were pooled on 2 levels to improve evaluation of population estimates. The first pooling used data from the second, third, and fourth, 20-night sampling periods. As noted earlier, during these periods only half of each area was sampled at a time; thus, two, 20-night sampling periods were necessary to produce estimates for each area. Because of this, data were pooled across adjacent 20-night periods. Although this treatment did not fully conform to the assumption of equal catchability, the time range of the pooling period was generally 3 months which probably minimized bias due to time.

The second pooling used all 20-night sampling periods. Data within each 20-night trapping period were pooled by recording only the first capture of a raccoon (Arnason and Baniuk 1980, Pollock 1982). Thus, data were considered on the basis of an animal being captured at least once or not captured in the overall sample period. By using this approach, the raccoon population was considered approximately closed over the 20-night period. This treatment was useful for increasing precision among all J-S estimates, especially as capture probabilities were low.

Raccoons exhibiting frequent movements between study areas were excluded from the population analysis. Raccoons caught more than 2 times in both areas were omitted from the analysis. Although this criteria was subjective it minimized inclusion of animals that

could contribute confounding biases in model calculations. Raccoons omitted from the analysis accounted for 5.2% (n=13) of the 248 individuals caught.

Five 20-night trapping periods provided data used in the J-S analysis. Because of constraints on the J-S model, estimates are not available for the first and last sampling periods. Live-trapping was continued in a follow-up study and data obtained from a sixth 20-night sample were incorporated into J-S analyses.

Closed population estimates of raccoons were obtained by two methods. In the first, trapping data were analyzed by CAPTURE, a computer program developed by Otis et al. (1978). CAPTURE provided a comprehensive analysis that included a test for closure of the mark-recapture data, a selection procedure for an appropriate model, and estimates of the population size. Selection of an appropriate estimator was based on goodness-of-fit tests of trap data to determine which of 8 models was best suited for calculating population size. CAPTURE models varied according to the type of unequal capture probability that was allowed in each model. All models assumed no dilution as sampling was conducted in less than 2 months. Population analyses by CAPTURE were conducted only on data collected in 1983 (the fifth, 20-night sample period). In this analysis raccoons previously marked were treated as newly captured.

Chapman's modification of the Petersen estimator (Seber 1982:60) was the second method used to produce a closed estimate. Data from the first and last 20-night periods were analyzed in this model.

To perform this analysis, data from the first 10 nights were considered as a marking period; and data from the remaining 10 trapping nights were treated as the resampling period. In the analysis of the last data set, raccoons previously marked were treated as newly captured. The following formula was utilized to calculate Petersen estimates:

$$\hat{N} = \frac{(M + 1)(n + 1)}{(m + 1)}, \text{ where}$$

$\hat{N}$ is the estimated population; M is the number of animals caught in the first sample; n is the number of marked and unmarked animals caught in the second sample; and m is the number of marked animals in the second sample. The variance formula for this estimator is:

$$\text{Var}(\hat{N}) = \frac{(M + 1)(n + 1)(M - m)(n - m)}{(m + 1)(m + 2)}$$

Coefficients of variation (CV) were calculated for all population estimates by dividing the standard error of the estimate by the estimate itself. These measures helped assess the relative precision between open and closed estimates (Lefebvre et al. 1982).

Ninety-five percent confidence intervals (C.I.) were calculated for all population estimates. The procedure presented by Otis et al. (1978:17) was utilized.

A chi-square contingency test was conducted on trap data to examine age differences in recovery rates of tagged raccoons. This analysis was run to evaluate age as a source of heterogeneity that could bias population estimates. Only data from the fourth

and fifth sample periods were used such that period 4 was the marking period and period 5 was the recovery period. Age was classified into 3 broad groups; these groups reflected a merging of age Classes 2 and 3, and Classes 4 and 5. Totals of tagged raccoons recovered and those not recovered in period 5 were summarized in a 3 x 2 contingency table.

Scent-Station Surveys

Data collection. Four scent-station lines were established in each study area. Lines were located to give a relatively even spatial distribution across each area (Figure 2). Sampling intensity (line per unit area) was similar in both areas because the areas were approximately the same size. Design of scent-station lines followed Brady (1979), Hon (1979) and Roughton and Sweeny (1982). Each line consisted of 10 stations that were generally located on alternating sides of the road along a continuous 2.9 (1.8 mi) km route. Located within 12 m of the road edge, stations were spaced at 0.32 km (0.2 mi) intervals along gravel roads.

Initially, a scent-station was constructed by clearing a 0.91 m circular plot in the ground cover and smoothing the mineral soil. Utilizing a box sifter, two persons prepared a tracking surface by sifting dry topsoil over the cleared plot. A station was activated by placing a cottonball saturated with synthetic fatty acid scent (Roughton 1979) in the center of the plot; the cottonball was elevated by a wooden tongue depressor. Fatty acid scent (FAS)

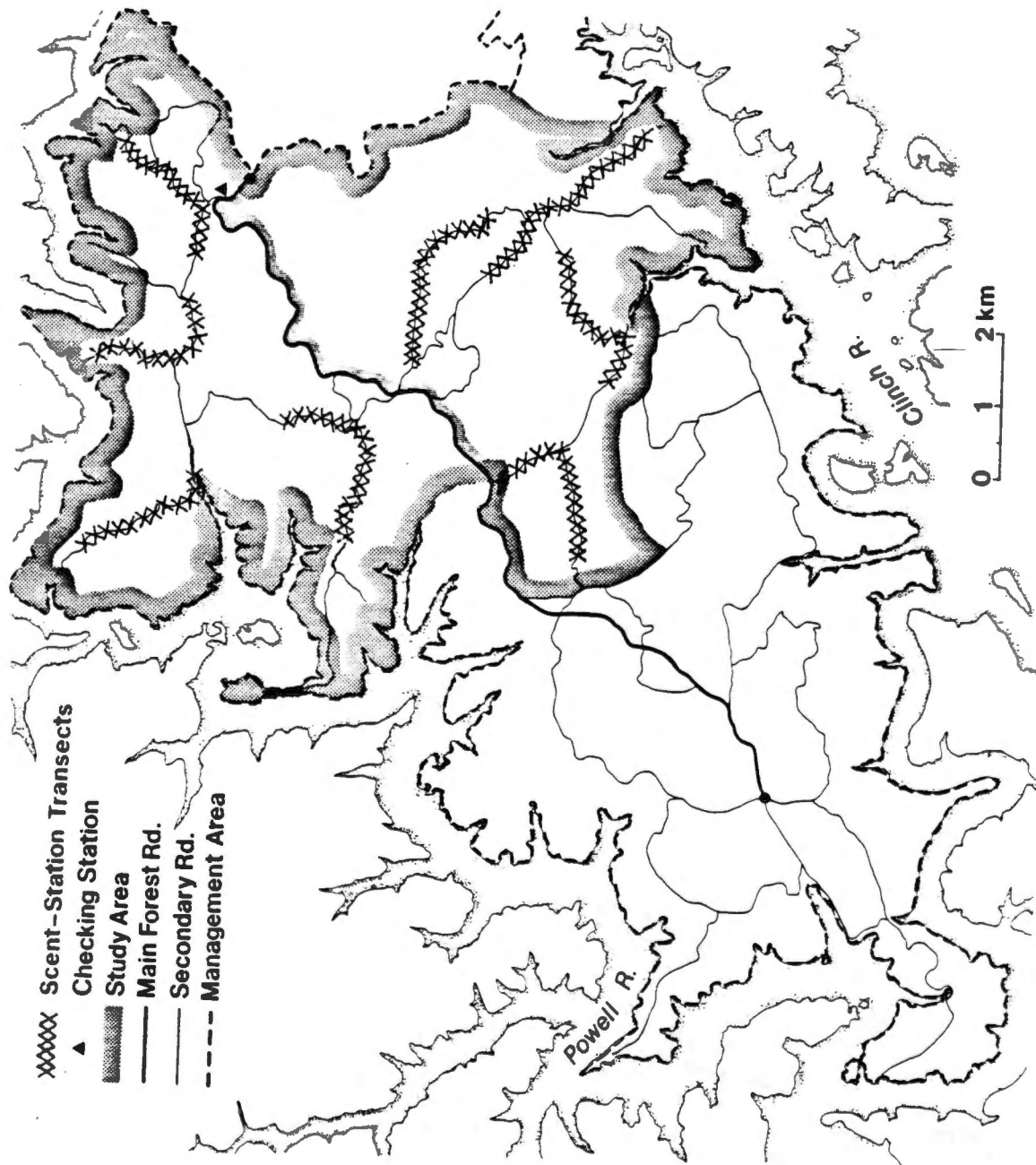


Figure 2. Map of scent-station survey transects on CSWMA.

was selected as the attractant based on its uniform quality and previous findings in East Tennessee that FAS was not significantly more attractive than three other attractants (Ken Johnson, Univ. of Tennessee, unpublished data). A thumb print was left on the sifted soil to serve as an indicator for determining if rain or freezing temperature had altered the tracking surface where animal tracks would not be apparent.

All eight lines were run concurrently when conducting a survey. Two field teams each consisting of 2 persons working out of a truck loaded with topsoil were utilized during each survey; each team prepared four lines. A map indicating line locations was carried by workers to insure lines were run identically in each survey. Surveys were attempted monthly, and new track surfaces were prepared and fresh attractant set each time. If rain rendered the survey inoperable, another attempt was made during the same month.

After one night of operation, each station was checked the following morning for animal tracks. Tracks at each station were identified to species and were recorded. In addition to stations cancelled by weather, stations disturbed by humans were recorded as inoperable. Stations altered by animals (i.e., knocking cottonball over, removing cottonball, rolling in set) were considered operable, thereby avoiding biases in editing the data (Roughton 1979). Other data recorded for each survey included the station number and its line number, condition of the station's tracking surface data, precipitation 24-hours prior to the survey, wind condition, and maximum and minimum temperatures.

Habitat features at scent-stations were investigated to determine their potential influence on visitation. Forest overstory type, forest presence, understory type, and topographic location were habitat components evaluated (Table 1). Assignment of these characteristics into categories was subjectively determined by examining vegetation composition and topography in the vicinity of a station. Relative frequency and dominant dbh size of canopy trees were factors scrutinized in selecting the overstory category; relative frequency of vegetation served as the primary factor used to evaluate understory type.

Data analysis. Because furbearer visitation to stations was low in this study, visits were averaged by line and expressed as a percentage of stations visited by a species per line for each survey (W. L. Sanders, pers. comm.). This manipulation was done to minimize the frequency of zero observations; this afforded improved power for detecting statistical differences in visitation rates. Because experimental errors were not likely independent and normally distributed with a common variance, data were transformed with the angular or arcsine transformation (Steel and Torrie 1960, W. L. Sanders, pers. comm.). Zero values occurring after pooling were counted as $1/4 (n)$ ($n=10$) before transforming observations to angles; this treatment improved the equality of variance in the angles (Steel and Torrie 1960). The least squares analysis of variance (ANOVA) was used to analyze relationships between visitation rates and survey lines, season and year.

Table 1. Habitat characteristics and their descriptive categories used in evaluating habitat effects on visitation response by raccoons on CSWMA, 1981-83.

Habitat Component	Descriptive Category
Forest presence	No forest Forest
Forest overstory type	Oak (<u>Quercus</u> spp.) Yellow poplar (<u>Liriodendron tulipifera</u>) Oak-hickory (<u>Quercus</u> spp.- <u>Carya</u> spp.) Oak-yellow poplar (<u>Quercus</u> spp.- <u>L. tulipifera</u>) Mixed hardwood Mixed hardwood-pine (<u>Pinus</u> spp.)
Understory type	Mixed hardwood Mixed pine regeneration Yellow poplar Dogwood (<u>Cornus florida</u>) Dogwood-Maple (<u>Acer</u> spp.) Maple
Topographic location	Creek border Dry lowland hollow Dry upland hollow Side of ridge Ridge top Gap Flat cove

Linear regression was used to investigate visitation response in relation to temperature and survey replication. Raccoon visitation rate for each survey (N=18) was established as the dependent variable; this visitation parameter represented a mean of the eight lines. Minimum and maximum temperatures, recorded at CSWMA during the day and night the survey was run, were evaluated as independent variables. Residual plots of error terms were evaluated to determine independence and homogeneity of variance and determine if the model was linear (Neter and Wasserman 1974).

Relationships between habitat components at scent-stations and visitation response were examined by the FUNCAT procedure (SAS 1982). FUNCAT evaluates categorical responses in a linear model similar to the approach performed in ANOVA on continuous data. Thus, FUNCAT was applicable because visitation response was measured in relation to habitat classifications or categories (Table 1). Weighted least squares of a logit function were used to generate minimum chi-square statistics (Grizzle et al. 1969). Similar categories of habitat components were pooled because visits were sparse for some habitat classes; this improved the validity of the FUNCAT analysis because low frequencies in categories can affect test reliability (Stedl 1981).

Relationship Between Visitation and Population Abundance

Spearman's correlation analysis was applied to analyze population estimates and visitation rates of raccoons. The Jolly-Seber estimator provided biannual estimates for each study area. Visitation parameters were drawn from data that most closely corresponded to population

estimates in terms of time and area. Spearman's correlation analysis was also used to investigate association between raccoon visits to survey lines and the number of different raccoon captures at traps nearest to corresponding survey lines. A weighted regression analysis was employed to evaluate relationships between visitation rates (independent variable) and capture success (dependent variable) of raccoons. Both of these proportions were transformed to a logit scale (natural log); logits were derived from a formula where a capture and a visit to a scent-station were considered as successes (Snedecor and Cochran 1967:497). The number of operable scent-stations was used as a weighting factor of the visitation rate (Snedecor and Cochran 1967:497). Independent and dependent variables analyzed in these regressions corresponded closely in time and space. Unless specifically noted, $P=.05$ was established as the significance level for testing hypotheses; however, all test probabilities were presented to clarify interpretation of analyses (Tacha et al. 1982).

CHAPTER IV

RESULTS AND DISCUSSION

Raccoon Trapping Parameters

From 30 July 1981 to 3 July 1983, five 20-night trapping periods were conducted resulting in 8,000 trapnights. A total of 248 individual raccoons were captured 649 times; 136 individual captures were made on the control area and 112 captures on the experimental area. A complete capture history for each raccoon is provided in Appendix A. An underestimate of trap success occurs when traps are sprung by both target and non-target species; thus trapping success was adjusted to provide accurate estimates of raccoon capture success. Nine other species of mammals were captured and collectively accounted for 702 individual captures (Appendix B) in addition to the 649 raccoon captures.

Monthly and seasonal capture success of raccoons varied considerably (Figure 3). Summer (16.5%) and spring (10.3%) were highest, followed by fall (8.3%) and winter (5.6%). These results differ from studies in Cades Cove, Great Smoky Mountains National Park where uniformly high capture success occurred in all seasons (Rabinowitz 1981). In that study, however, traps were placed in optimal trapping sites throughout the year. Moore (1983) reported highest capture success in fall and winter in western Tennessee. He believed these findings were influenced by food availability and rate of food intake.

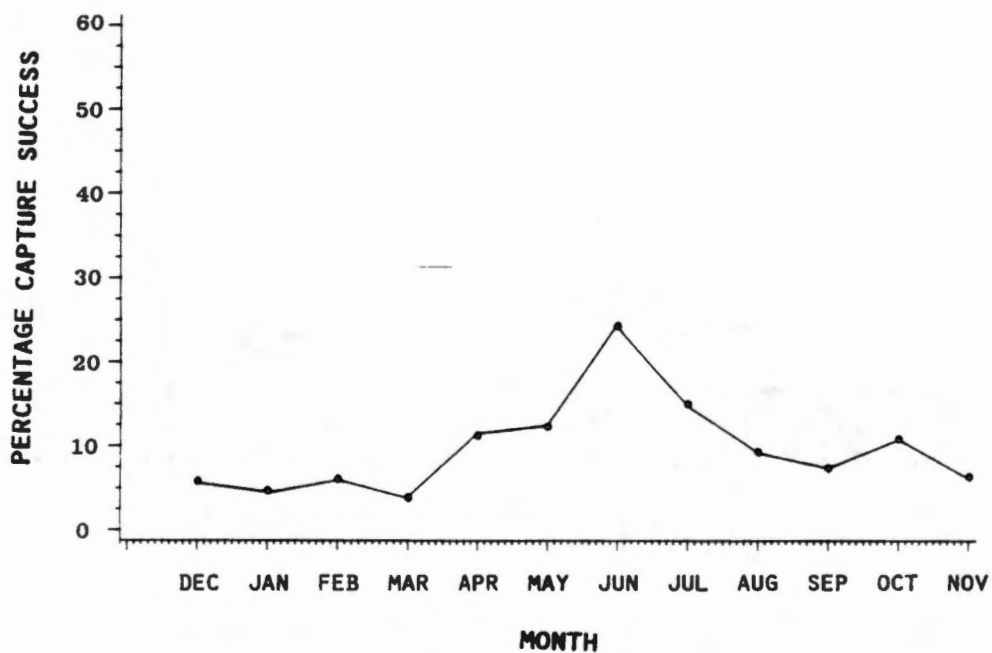


Figure 3. Monthly capture success of raccoons caught on CSWMA, 1981-83.

Capture success was significantly influenced by the month of capture ($F=6.32$, $P<.0001$). Similar patterns of monthly capture success occurred during both years of the study. Monthly differences in capture success were probably related to reproductive activity and dispersal of raccoons. The sharp rise in capture success that occurred in April (Figure 3) coincided with breeding activity of males (see Breeding and Parturition Chronology, p. 42). Rabinowitz (1981:34) found that breeding activity of raccoons in Cades Cove peaked in April.

High trapping success in late spring and a subsequent peak in June were likely due to dispersal of yearling raccoons and movements by parous females. Parturition at CSWMA peaked in June (see Breeding and Parturition Chronology, p. 45) and adult females emerging from maternity dens may have contributed to increased capture success. Fifty-three percent of females captured for the first time in June 1982 and 1983 were lactating. Of the 56 raccoons captured for the first time in June 1982 and 1983 combined, 82% were either Class 1 or Class 2 age animals. Beginning in May, the percentage of yearling raccoons increased in both years. Yearlings contributed 6.9% in April, 25% in May, 26% in June, and 12% in July to the total sample of raccoons whose age was known; these results indicate dispersal occurred and coincided with parturition. Rabinowitz (1981:55) suggested that dispersal of yearling raccoons occurred in June and coincided with parturition. He also suggested that young males were more likely to disperse than young females.

Trapping success also may be related to population density. Capture success during 1982-83 was 14.8% compared to 9.1% in 1981-82; this difference was significant ($F=2.96$, $P<.08$). The increase was similar to an increase shown in population estimates (see Population Estimation, p. 46). Capture success was generally reduced during fall months (Figure 3). The small rise which occurred in October may have been due to an increased capture of young-of-the-year raccoons (see page 43). Woods (1978) also reported increased trapping success in October on Chuck Swan and believed it was due to increased movements of juveniles. These findings appear to indicate that capture success by year was related to population density irrespective of the influences of reproductive activity and dispersal.

Population Characteristics

Sex Ratios

The sex ratio among the 248 raccoons captured was 121 males per 100 females (55% males) and did not differ significantly ($\chi^2=2.51$, $P=.12$) from an expected 1:1 ratio. In the first year of study the juvenile sex ratio was 80 males per 100 females, compared to an adult ratio of 115 males per 100 females. Neither adult nor juvenile sex ratios differed significantly ($\chi^2=.67$, $P=.37$; $\chi^2=.44$, $P=.49$, respectively) from a 1:1 ratio. In these analyses, Class 1 age raccoons were considered juveniles, whereas raccoons aged Class 2 or older were considered adults. In contrast with the first year of study, the juvenile sex ratio in 1982-83 (200 males per 100 females) differed significantly from the expected ($\chi^2=5.9$, $P<.02$).

Although sex ratios generally did not differ from 1:1, the mean number of captures per male (3.0) was significantly ($t=2.94$, $P<.004$) greater than for females (2.04); this result suggests a livetrapp bias favoring capture of males. Variability in sex ratios of raccoons is common and difficult to explain; it can be affected by collection technique, season and area differences (Johnson 1970:228). Sex ratios favoring females have been reported by some researchers (Stuewer 1943, Lehman 1977, Keeler 1978:50, Rabinowitz 1981:24) whereas sex ratios skewed toward males were evident in the present study and others (Johnson 1970:116, Urban 1970, Sonenshine and Winslow 1972, Warr 1978:53).

Age Structure

An age pyramid (Figure 4) was compiled from data using original captures of raccoons obtained over 2 years of trapping. Nearly equal numbers of males and females were represented in all age classes except Class 5 animals where more females were captured. Rabinowitz (1981:25) and Keeler (1978:27) found higher numbers of females than males in Class 5 samples. The above findings may suggest differential mortality of males in Class 5.

The aging technique employed in this study was not completely accurate and overlap between age groups undoubtedly occurred. Consequently, grouping of certain age classes was done to make broad interpretations of age data. A young:adult ratio of 1.4:1 was obtained by grouping Classes 1 and 2 as young animals and Classes 3, 4, and 5 as older animals (for the first year). In contrast, Rabinowitz (1981:27) reported a young:adult ratio (same grouping) of 2:1 from

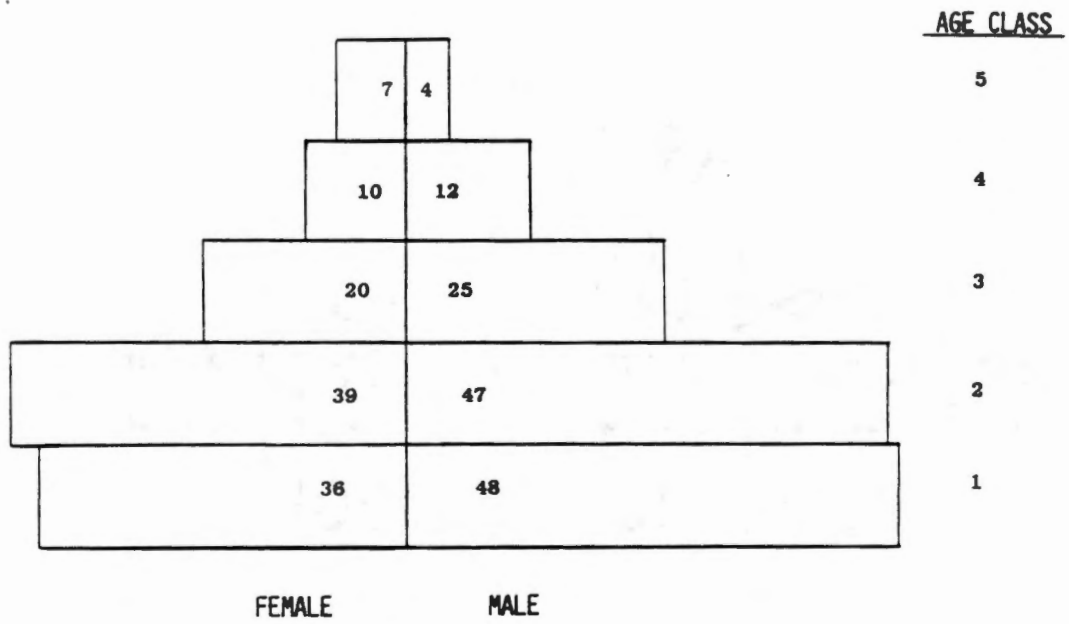


Figure 4. Age pyramid by sex of raccoons caught on CSWMA, 1981-83.

a protected upland population with relatively high density; this contrast could be the result of sampling differences or a reflection of actual differences in population structure.

Little temporal variation in age ratios was indicated. Class 1 animals (i.e., juveniles) comprised 23% (n=36) of the population in the first year and 24% (n=41) in the second year. Changes in age ratios may reflect changes in natality or juvenile mortality (Tanner 1978:62). However, using age ratios alone to evaluate population condition may provide ambiguous information (Caughley 1974).

Differences in age structure between areas were evaluated (Figure 5). In general, the experimental area contained a larger proportion (82%) of older raccoons (Class 5) but had a smaller proportion (42%) of younger raccoons (Class 1) than the control area. When data were pooled across sexes, there were no significant differences ($\chi^2=8.7$, $P=.08$) in the distribution of age classes between areas; this could indicate that raccoons from both study areas were actually components of one large population.

Longevity and Mortality

Of the 248 raccoons captured and aged in this study, 22 (8.9%) were estimated to be at least 58 months old and 11 (4.4%) were estimated to be older than 86 months (Figure 4). In addition, four raccoons marked in previous studies (1976, 1977) at Chuck Swan were recovered during this study; based on dates of their original capture, minimum ages of 2 that were reported dead were 5 years old. The other 2 animals, both females, were livetrapped and aged as Class 5

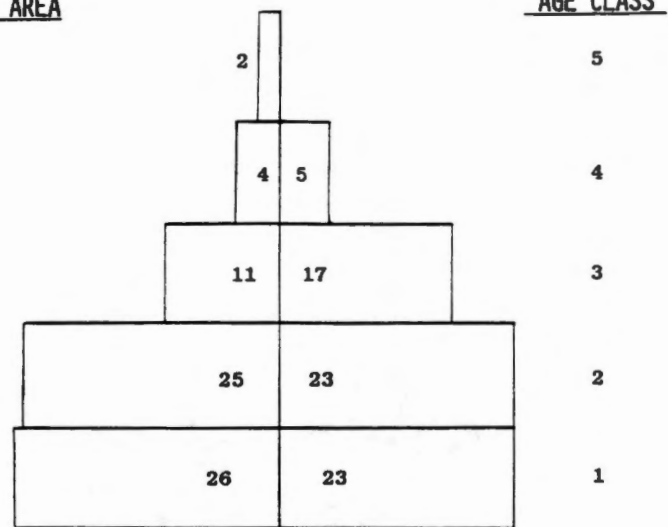
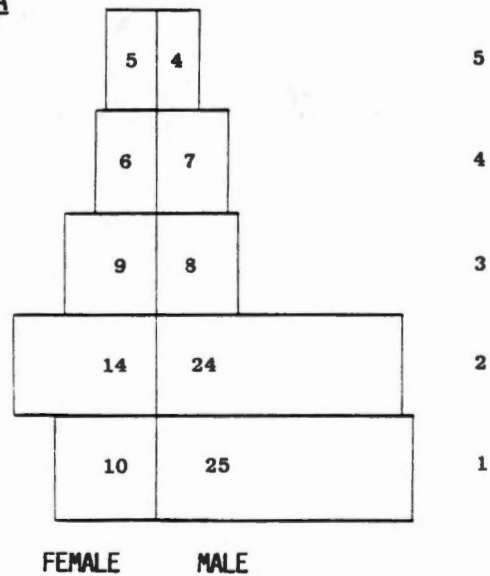
CONTROL AREAEXPERIMENTAL AREA

Figure 5. Age pyramids for raccoons captured (initial captures only) on the control and experimental areas, CSWMA, 1981-83.

(>7-years) raccoons. The estimated minimum age of one of these individuals was 9 years and 4 months. It appears that at least 9 years approximates the maximum longevity of raccoons at Chuck Swan. Rabinowitz (1981:57) believed the maximum longevity of raccoons in Cades Cove was near 7 years. Woods (1978:70) reported a 10-12 year old female raccoon from CSWMA based on counts of cementum annuli; this animal was harvested during a period when hunting was allowed. Comparisons of maximum longevity among areas likely are not valid because of differences in methods of age determination, fluctuations in annual mortality rates, and environmental differences among areas.

Fifteen raccoon mortalities were documented during the study; causes were both natural and unnatural (Table 2). In 6 instances the causes of death were unknown. Unnatural or human related causes accounted for 7 of 9 (78%) known mortalities; of these 7 cases, 3 raccoons were reportedly taken by hunters outside CSWMA, 1 was an apparent road kill off of Chuck Swan, and 3 were killed by dogs while raccoons were in livetraps or recovering from drugging. Research related kills are not considered in forthcoming discussions. Although hunting was prohibited on CSWMA during the study, the 3 tagged raccoons taken by hunters indicate the potential influence of hunting in the areas surrounding Chuck Swan. Minser and Pelton (1982:18) believed that excessive harvest was a primary factor for low populations of raccoons on private lands in East Tennessee.

One definitive case of natural mortality, a diseased raccoon, was observed during this study. On 20 May 1982 a sick and emaciated

Table 2. Known raccoon mortalities on or near CSWMA from February 1982 to June 1983.

Cause of Mortality	Date of Mortality or Report of Mortality	Tagged	Sex	Age Class	Location
Dog kill	17 Feb. 1982	No	mb	4	Ellison Hollow
Dog kill	22 Feb. 1982	N/A ^a	N/A	N/A	Brassfield Bend
Probable road kill	Early March 1982	Yes	M	N/A	Ellison Hollow (outside CSWMA)
Unknown	3 Apr. 1982	No	F	1	Mossy Springs
Unknown	9 Apr. 1982	Yes	M	5 years	Rifle Range
Unknown	9 Apr. 1982	(previous study)			(Long Hollow Ridge)
Unknown	9 Apr. 1982	No	M	2	Rifle Range
Unknown	9 Apr. 1982	No	N/A	N/A	(Long Hollow Ridge)
Unknown	13 May 1982	No	F	2	Rifle Range
Canine distemper	20 May 1982	No	M	3	(Long Hollow Ridge)
Euthanized for necropsy, animal paralyzed	6 July 1982	No	M	2	Long Hollow
Unknown	27 Nov. 1982	Yes	N/A	5 years	Dividing Ridge
Hunter kill	13 Nov. 1982	(previous study)			Henegar Bend
Hunter kill	29 Nov. 1982	Yes	M	1	Long Hollow
Hunter kill	mid-Dec. 1982	Yes	M	1	Flat Hollow, north of Powell River (outside CSWMA)
Dog kill	14 June 1983	Yes	F	2	Peavy Hollow (outside CSWMA)
			M	1	Sharps Chapel (outside CSWMA)
					Dividing Ridge

aN/A = not available.

bm = male, F = female.

raccoon was captured and died approximately 6 hours later. A necropsy revealed the raccoon died of acute encephalitis caused by a distemper infection (Final Necropsy Report, C. Helman, Dept. of Pathobiology, Univ. of Tennessee Veterinary Hospital). Subsequent blood sampling and testing revealed that 4 of 18 raccoons in 1982 (Table 3) showed positive titers to canine distemper virus (CDV). Seventeen samples from April to July 1983 revealed no other positive titers of CDV in raccoons. All four raccoons displaying CDV titers were recaptured in 1984 and appeared healthy (D. Kocka, pers. comm.).

The diagnosis of the ill raccoon and presence of CDV titers in four raccoons indicated that the Chuck Swan population was exposed to canine distemper, probably in the spring of 1982. The extent of the transmission of this disease is uncertain, but it is unlikely the disease reached epidemic proportions based on relatively comparable spring and summer population estimates (see Population Estimation, p. 46). In addition, this incidence of CDV may be related to 5 unknown raccoon mortalities in the control area. These 5 cases were detected within 1-1/2 months and within 2.4 km to the distemper infected raccoon discovered on 20 May 1982. The apparent outbreak of distemper may explain the cause of these mortalities.

Another incident may have led to an eventual natural mortality. A raccoon was livetrapped that was paralyzed in the hind quarters. This animal's motor ability was completely lost when held for observation (1 day); this indicated the raccoon would have eventually died in the forest.

Table 3. Raccoons showing positive titers for canine distemper on CSWMA, 1982.

Animal	Date of Sample	Sex	Age Class	Antibody Titer	Physical Condition	Location
No number given ^a	20 May 1982	M ^b	2	1:80	Poor, weighed 2.3 kg	Dividing Ridge
117	28 July 1982	F	3	1:10	Good, weighed 2.7 kg	Fletcher Ridge
273	6 Sept. 1982	M	2	1:10	Fair, weighed 3.6 kg	Lindamood Ridge
297	12 Oct. 1982	F	2	1:10	Good, weighed 3.2 kg	Clear Creek
301	21 Dec. 1982	F	3	1:10	Excellent, good fat deposit, weighed 4.5 kg	Long Hollow Ridge
302	22 Dec. 1982	M	2	1:10	Excellent, good fat deposit, weighed 5.9 kg	Clear Creek

^aAnimal died before release.

^bM = male, F = female.

Sample sizes were too small to detect major differences in mortality by sex or age. Despite this limitation, it should be noted that 3 of 4 raccoons killed outside Chuck Swan were males. Previous research indicates that male raccoons exhibit greater movements than females (Urban 1970, Fritzell 1978, Woods 1978, Rabinowitz 1981); this characteristic may contribute to increased mortality of males on Chuck Swan. Also, mortalities were observed over a wide range of age classes (3 age Class 1, 3 age Class 2, 1 age Class 3, 2 age Class 4). When the 2 lower classes were grouped as young raccoons ($N=6$) and the other classes as old animals ($n=3$), young raccoons exhibited higher death rates. Johnson (1970:124) reported highest mortality among raccoons in Alabama during the first 2 years of life.

Estimation of Survival Rate

Program POPAN provided estimates of seasonal survival based on Jolly (1965) and Seber (1965) models. The assumption of equal survival was accepted in this study, thus estimates were extended to the overall population in the respective study areas. Estimates were not stratified by age or sex and should be considered as overall estimates of survival. Due to model constraints, survival rates were obtained for only the first four 20-night sampling periods (Table 4). Three months was generally the length of the sampling period; however, the first estimates in each area were obtained from 2 month (control area) and 4 month (experimental area) periods. Time differences between these estimates were standardized on a 3 month basis, facilitating comparisons by time.

Table 4. Jolly-Seber estimates of survival rates for raccoons on the two study areas, CSWMA, 1981-83.^a

Fall 1981	Winter 1981-82	Spring 1982	Summer 1982	Fall 1982
<u>Control Area</u>				
.58 (.08) ^b		.96 (.08)	1.0 (.13)	.77 (.10)
<u>Experimental Area</u>				
	1.0 (.33) ^b	.61 (.13)	1.0 (.20)	.52 (.10)

^aAssociated standard errors are given in parentheses.

^bStandard error calculated by the delta method approximation (Seber 1982:7-9).

Particular care must be taken in interpreting survival estimates because they measure the gross rate of loss in the population. Survival rates reflect losses due to both death and emigration (Jolly 1965), and this complicates assessment of mortality effects even when ancillary information is available. Survival rates were of limited value in this study because death and emigration losses were not known.

The first estimates of survival in each area were appreciably different. However, the 2 areas were sampled at different times and for different lengths of time. Sampling in the control area was conducted during the fall from September until early December, while sampling on the experimental area occurred in December and January. The survival rate (.58) in the control was lowered after weighting to the other 3-month estimates. However, this estimate compared favorably to other fall estimates from both areas. In contrast, the Winter 1981-82 estimate was inflated because it was obtained from a shorter sampling interval. A high standard error (.33) indicates the imprecision of this estimate.

Although specific interpretations of survival rates are difficult to make, emigration from the experimental area may have led to decreased estimates of survival for that area. Survival rates for the control area were higher than the experimental area in both spring and fall in 1982 (Table 4). However, differences between the 2 areas were significant for spring ($P < .048$) but not for fall ($P = .10$). Movements of raccoons are greater in spring and fall (Fritzell 1978, Rabinowitz 1981:47). Such seasonal movements may have occurred on CSWMA and

contributed to emigration from the sampling areas. If this occurred, it was likely more prevalent on the experimental area which contains a longer boundary (Figure 1, p. 10) from which emigration could occur. CAPTURE analysis revealed that the experimental area failed to meet the closure assumption (see Population Estimation, p. 51) during spring in 1983. Although this test did not evaluate the same spring when survival rates differed between areas, the test suggested that significant emigration occurred on the experimental area during this season.

While emigration may have contributed to decreasing survival rates, mortality probably occurred during spring and fall. Raccoons exhibit greater movements during these periods, and increased mortality might be expected due to greater exposure to disease (Rabinowitz 1981:60) and hunting outside CSWMA (see Longevity and Mortality, p. 35). As discussed earlier (p. 37), a CDV outbreak was suspected during spring in 1982; this disease may have contributed to the decreased survival rate from winter to spring on the experimental area.

- Chronology of Breeding and Parturition

Breeding in 1982 was determined by back dating estimated ages of 12 pre-weaned raccoons and assuming an average gestation period of 63 days (Table 5) (Hamilton 1936, Stuewer 1943). The breeding season for raccoons at Chuck Swan ranged from late February to late April with a peak occurring in April.

Pregnant females were first observed in mid-May in 1982 (Table 6). The first observations of lactating females occurred on 17 May

Table 5. Estimated ages and parturition dates of captured young-of-the-year raccoons on CSWMA, 1982.

Identification Number	Capture Date	Estimated Age (Days) ^a	Range of Parturition Date
260	30 July	86- 97	25 April-6 May
263	2 August	86- 97	28 April-9 May
270	18 August	106-112	29 April-5 May
275	7 September	106-112	19 May-25 May
276	7 September	106-112	19 May-25 May
277	8 September	86- 97	4 June-15 June
280	17 September	112	29 May
282	18 September	86- 97	14 June-25 June
284	1 October	97-106	18 June-27 June
285	1 October	97-106	18 June-27 June
286	2 October	112	13 June
287	2 October	106-112	13 June-11 June
N=12		Range of parturition:	25 April-27 June

^aTechnique as prescribed by Montgomery (1964).

Table 6. Number of adult female raccoons examined for reproductive condition in 1982 and 1983 on CSWMA.

Capture Period	1982			1983		
	Number Examined	% Pregnant	% Lactating	Number Examined	% Pregnant	% Lactating
12-21 May	5	60	40	6	83	17
22-31 May	3	67	33	6	33	50
1-8 June	4	0	100	5	0	60
9-15 June	3	0	67	1	0	100
16-30 June	1	0	100			
1-9 July	3	33	67			
10-20 July	8	0	88			
21-31 July	3	0	100			
1-17 Aug.	2	0	50			
18 Aug.-6 Sept.	1	0	100			
17 Sept.-3 Oct.	3	0	67			

and 5 June 1982, and the numbers of lactating females in the capture sample increased in late June and July (Table 6). Estimated ages of 12 pre-weaned raccoons during summer and fall of 1982 indicated birth dates ranged from late April to late June with most occurring from mid-May to mid-June (Table 5). In 1983, pregnant females were captured from mid-May until mid-June (Table 6). Lactating females were caught from mid-May to the end of sampling in early July (Table 6). Thus, most parturition occurred from mid-May to mid-June in 1982 and 1983, but data for 1983 were limited.

Periods of breeding and parturition found in the present study compare favorably with the data of Woods (1978:58) who found breeding in February and March and parturition occurring from April to June on CSWMA. However, results of the current study may be more accurate because they were based on relatively accurate ages of pre-weaned raccoons, whereas Woods used an eye lens method that aged juveniles only by month. A slightly later range of parturition (mid-May to early August) was reported for raccoons in Cades Cove, GSMNP by Rabinowitz (1981:30) who employed the same aging method used in the present study. A peak in parturition in June in Cades Cove corresponded to a late March and early April breeding period. A similar pattern of breeding and births likely occurs throughout East Tennessee since the initiation of raccoon breeding appears to be related to latitudinal properties, specifically photoperiod (Bissonnette and Csech 1938, 1939) and temperature (Sanderson and Nalbandov 1973).

Population Estimation

Open model estimation. Jolly-Seber estimates were used to show seasonal trends and annual differences in the raccoon populations over the 2-year study. Population fluctuations were similar for both areas (Figure 6). The population on the control area increased slightly from spring to summer in 1982 and was likely due to increased captures of dispersing yearlings on that area. Young-of-the-year raccoons were not captured in summer sampling periods presumably because they did not exhibit significant movements until late summer when they were first captured. Considerable reproductive recruitment was illustrated in fall estimates for both areas. The control area showed a significant 112% increase from summer to fall in 1982 ($P < .04$); the experimental area revealed a significant (171%) increase for the same period ($P < .03$). Declines from winter-spring to summer occurred in both areas. Summer estimates indicated that both populations had increased from the previous summer, though the increases were not significant ($P = .18$, control; $P = .07$, experimental).

The above seasonal trends and annual differences in population were compared to those from other studies, though few researchers have documented seasonal trends in raccoon population size. A population increase from 20 to 43 individuals (115% increase) between July and October was reported for a study area in Minnesota but no data were provided on changes of annual density during the 2-year study (Mech et al. 1968). In a marsh habitat, a 33% increase in a raccoon population from spring to fall was reported by Urban (1970); he

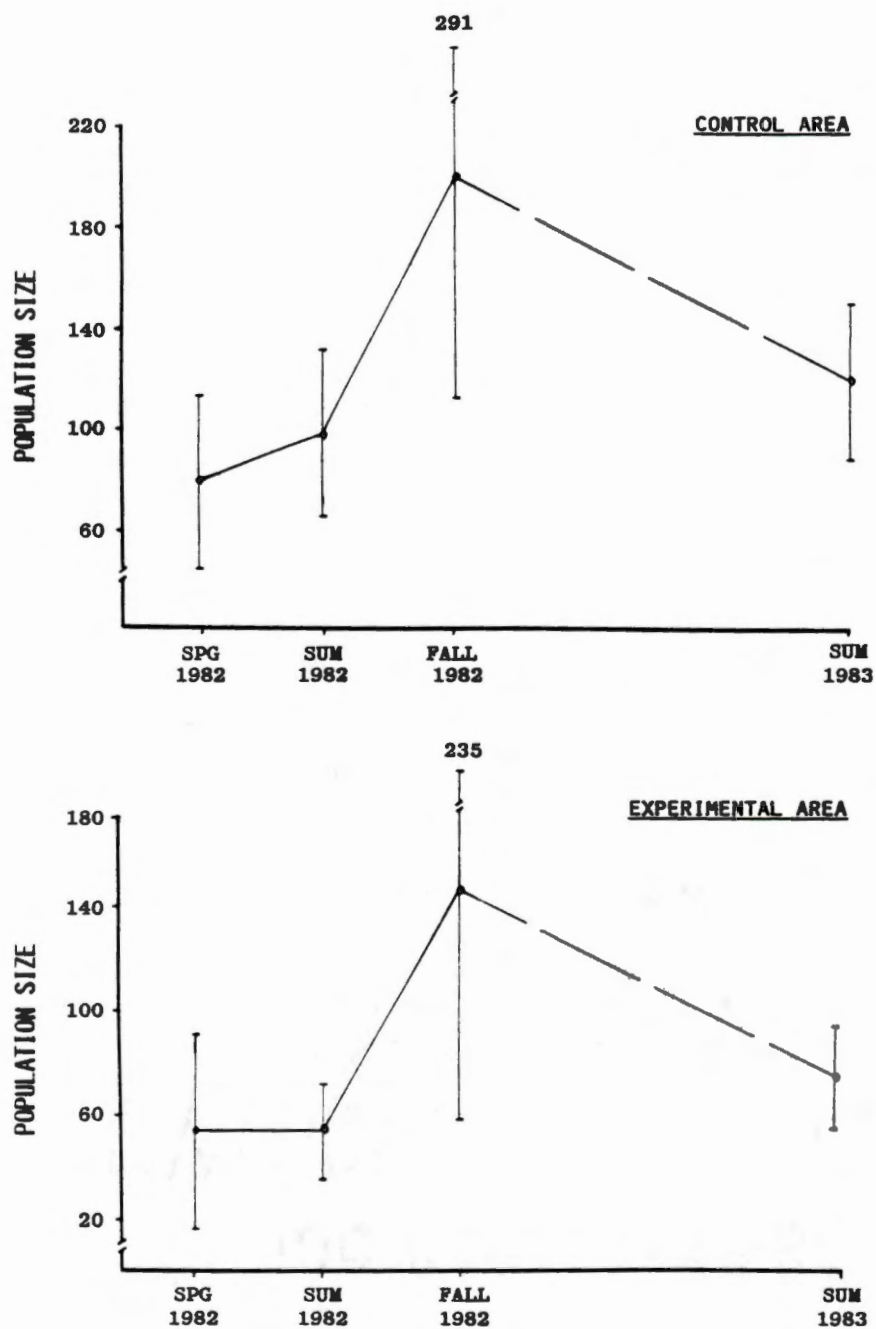


Figure 6. Jolly-Seber estimates of population size on the two study areas on CSWMA, 1982-83. Ninety-five percent confidence intervals are provided.

estimated a spring population of 87 which was 38% lower than the estimate for the previous fall. The accuracy of this decline is uncertain but the decline was likely underestimated because the spring estimate considered only mortality from trapping. On Chuck Swan the average percentage decline from fall (post-reproduction) to summer (pre-reproduction) was 45%, similar to the 38% decline from fall to spring reported by Urban. Decreases in population estimates in the present study may not only reflect mortality but estimates may also have been lowered by raccoon emigration from sample areas. Survival estimates (Table 4, p. 40) for both spring and fall (including Fall 1982) were lowest of the seasons sampled suggesting that raccoons may have emigrated from sampling areas. It is unlikely that decreases in estimates were representative of the overall population at Chuck Swan because raccoons in sample areas were contiguous with the overall population at Chuck Swan.

Although seasonal trends in population size for the 2 areas were similar, quantitative differences between areas were evident. All four J-S estimates indicated the control area contained a denser population (Figure 6). This difference was maintained during the second year despite a greater growth rate from recruitment on the experimental area. Reasons for this overall disparity were not clear. Size of the area sampled in each study area differed marginally (43 ha) in favor of the control area. Habitat characteristics are generally comparable in both areas, although the control area may contain a slightly greater amount of mature oak forest and may have a potentially higher carrying capacity.

Closed model estimation. The Chapman modification of the Petersen model was used to compute population estimates for the first and last 20-night sample periods (Table 7). The Petersen model produced a fall estimate of 115 (C.I., 31-199) on the control area. The assumption of closure was violated in this estimate because recruitment of young raccoons occurred during fall. Recruitment likely caused an over-estimate of raccoons on the control area. The estimated winter population was 42 (C.I., 12-72) on the experimental area; this estimate probably was robust to closure because sampling occurred during early winter when raccoon movement is minimal (Rabinowitz 1981:53). High coefficients of variation were associated with both estimates and were likely due to low capture success during these seasons. Despite variations in the sampling period, the large difference between the fall estimate on the control area and the winter estimate on the experimental area suggested a higher raccoon density occurred on the control area.

The Petersen estimate in early summer on the control area was 96 (C.I., 67-125) compared to 92 (C.I., 62-122) on the experimental area (Table 7). Greater precision of estimates in 1983 resulted from increased capture probabilities and a greater number of marked raccoons in model computations. Although the estimated number of raccoons was higher on the experimental area, it is likely that capture data from the control area performed poorly to model assumptions and consequently yielded an unreliable estimate (discussed later). In contrast, the Petersen estimate for the experimental area was more reliable than other closed estimates (discussed later).

Table 7. Closed population estimates of raccoons on the two study areas on CSWMA, 1981-83.^a

Fall, 1981	Early Winter, 1981-82	Early Summer, 1983			
Petersen Model ^b	Petersen Model	Petersen Model ^b	Model M ₀	Model M _t	Model M _h
<u>Control Area</u>					
115 ± 84 (37%)		96 ± 29 (15%)	102 ± 28 (14%)	101 ± 26 (13%)	148 ± 43 (14%)
<u>Experimental Area</u>					
	42 ± 30 (36%)	92 ± 30 (16%)	81 ± 18 (11%)	81 ± 18 (11%)	120 ± 32 (13%)

^aNinety-five percent confidence intervals and coefficients of variation (in parentheses) accompany each estimate.

^bChapman's modification of Petersen Model (Seber 1982:60).

Trapping data collected during the last 20-night period were also analyzed by the CAPTURE program. The first procedure in CAPTURE tests for population closure. Data from the control area met the closure hypothesis ($z=-0.22$, $P=.41$), but data from the experimental area did not ($z=-1.65$, $P<.049$). Otis et al. (1978:66) stated, "that closure is difficult to test for because some types of variations in capture probabilities (i.e., behavioral) are difficult to distinguish from a failure of closure." The model selection procedure for the experimental area indicated some behavioral variation in capture probabilities, thus suggesting the closure test may not have been reliable. The above results tend to support the validity of CAPTURE models for analyzing capture data from this study.

CAPTURE selected Model M_0 as the most applicable for analysis of data from the control area. The population estimate by Model M_0 was 102 (C.I., 74-130) for early summer of 1983 (Table 7). This model is the most simplistic of the 8 models in CAPTURE and assumes uniform capture probabilities. Otis et al. (1978:24) believed Model M_0 was biased because most wildlife species exhibit some form of variation in capture probability.

To assess bias of Model M_0 , other CAPTURE models were examined. The heterogeneity model, M_h was the next most appropriate model selected by CAPTURE. Known also as the Jackknife estimator, Model M_h assumes heterogeneity where probability of capture may vary by age, sex, social status and other factors (Otis et al. 1978:33). This model, however, does not allow for variation in the animal's

capture history (i.e., trap avoidance, trap addiction). The Jackknife model produced a population estimate of 148 (C.I., 105-191) for the control area (Table 7). In contrast, Model M_t , which assumes the probability of capture changes over time, produced a lower estimate of 101 (C.I., 75-127). The Model M_t estimate was similar to the Petersen and Model M_0 estimates, which assume uniform capture probabilities. The comparison between Model M_t and Model M_0 suggested time was not a major factor in biasing estimates.

The Jackknife estimator was more robust than other closed estimates for the control area. Shown earlier (p. 31), sex contributed to heterogeneous capture rates where males were more prone to recapture than females. Age of raccoons also contributed to heterogeneous capture probabilities as evidenced by a significant difference ($\chi^2=33.7$, $P<.01$) in recapture rates among 3 age classes from Fall 1982 to Summer 1983. The Jackknife model tends to be a robust estimator when many animals are caught and have high recapture frequencies (Otis et al. 1978:35). Data from the control area appeared to satisfy the above conditions suggesting that the Jackknife estimate was less biased than other estimates because heterogeneity was assumed. Moreover, as opposed to the Jackknife estimate, the other model estimates appeared to be underestimates. General estimators (Models M_0 , M_t) tend to underestimate population size due to heterogeneous capture probabilities (Otis et al. 1978:24).

The model selection procedure determined Model M_{bh} as the appropriate estimator for the experimental area. This model allows

both a behavioral bias after the first capture and heterogeneity of capture probabilities (Otis et al. 1978:40). Population size estimated by this model was 64 (C.I., 53-75). Compared to other estimates, this measure was low and was probably unreliable due to a low number of recaptures (K. Pollock, pers. comm.). Model M_h was selected as the second most appropriate model. This estimator provided a population estimate of 120 (C.I., 88-152). Compared to all other closed estimators, the Jackknife estimate was the highest (Table 7). The Petersen estimate appeared intermediate to the other estimates. Noted earlier, capture probabilities of raccoons varied by sex and age. Dispersal during June sampling and the increased opportunity of emigration across a long boundary may have contributed heterogeneous capture probabilities. The above effects likely produced underestimates in the general models (Petersen, Models M_0 , M_t) which did not assume heterogeneity.

Comparisons of closed and open estimators. All closed model and Jolly-Seber estimates indicated that the control area supported a denser raccoon population. This pattern was maintained across all seasons that were sampled. In general both types of estimators exhibited annual population increases in each area. Comparison of summer J-S estimates revealed distinct population increases for the second year in both areas (Figure 6, p. 47). The Petersen model was the only closed estimator allowing comparisons across years. Estimates for the experimental area indicated a 54% increase (42 to 92) in population size from the first to second year. Petersen

estimates for the control area did not demonstrate an increase between years but this may have been due to poor model performance in the 1983 estimate or differences in the time of the estimates.

In this study and others (Woods 1978:64, Moore 1983), heterogeneity of capture was demonstrated as a discernible characteristic in raccoon capture data. Comparison of Jackknife and Jolly-Seber estimates in 1983 further substantiated this source of unequal catchability and addressed bias in the J-S estimates. Comparison of Jackknife and J-S estimates for summer 1983 showed higher Jackknife estimates in both areas (Table 8). Both models exhibited good precision as indicated by low coefficients of variation and facilitated comparisons between areas. The fact that Jackknife estimates were higher demonstrated strong heterogeneity of raccoon capture since the J-S model assumes equal catchability. Pollock (1982) demonstrated through simulation that the J-S estimator underestimates population size when capture data fail to meet the equal catchability assumption.

From the above and other evidence of heterogeneity, it is likely that the J-S estimates underestimated both study area populations throughout the study. This finding raises the question of how much of an underestimate was produced in the J-S estimates. This question is difficult to assess because the accuracy of the Jackknife estimator is unknown though it likely produced the most robust estimates. The J-S estimate ($\hat{N}=119$) probably represents the lower bound and the Jackknife estimate ($\hat{N}=148$), the upper bound of the population on the control area in Summer 1983. The Petersen

Table 8. Comparison of open and closed model estimates for summer 1983 on CSWMA.

Model	Estimate	Coefficient of Variation, %	95% Confidence Interval
<u>Control Area</u>			
Jolly-Seber	119	9	97-141
Jackknife	148	14	105-191
<u>Experimental Area</u>			
Jolly-Seber	76	9	62-80
Jackknife	120	13	88-152

estimate ($\hat{N}=92$) may more closely approximate the lower limit for the population on the experimental area because the J-S estimator ($\hat{N}=76$) was especially subject to heterogeneity in Summer 1983 and resulted in an underestimate. The Jackknife estimate of 120 raccoons probably indicates a reasonable upper bound for the experimental area.

Density Estimation

In essence, density measures are most useful for comparative purposes, particularly over time and between locations. Estimation of absolute density in this study was conducted primarily for the purpose of comparison to other studies.

The phenomenon of edge effect can cause bias in density estimation if it is not considered. Because animals at the edge of a trapping grid (or whatever scheme used) do not have all of their home range within the grid, the area of effect is greater than the actual area trapped (Dice 1938, Otis et al. 1978:67); this influence is known as edge effect. The area outside of the trapping grid that is affected by trapping is termed the boundary strip. If the edge effect is not accounted for in calculating density, an over-estimate will result because the population estimate includes animals captured at the edge of the trapping area although these animals are not strictly resident on the area (Otis et al. 1978:67).

Three basic approaches are used to resolve the problem. The first method derives a home range estimate based on recapture

locations, then uses the radius of the estimate to derive a boundary strip. The second estimates a strip from data drawn from selected subgrids (Otis et al. 1978:68-74). The last approach utilizes assessment lines designed to directly estimate the effective trapping area; this method has provided encouraging results with raccoons in West Tennessee (G. Baumgardner, Memphis State University, pers. comm.).

In this study the effective area of trapping was considered in the study design. Adjustment for edge effect was accomplished by setting traps in adjacent concentric quadrats such that the quadrat radii represented the radius of an average raccoon home range in East Tennessee (Hardy 1979). This approach was comparable to the first method described above except that home range radius (boundary strip estimate) was obtained from another source other than recapture data in the actual study. It was believed that determining home range from recapture data in this study would have been biased as a function of trap site locations. Additionally, because the study area size was relatively large, the influence of the boundary strip was minimized as the importance of the boundary strip decreases with increased trapping area (Otis et al. 1978:120). Despite these considerations, the edge effect may have occurred as was suggested by known migrations of raccoons caught between study areas.

To calculate absolute density, population estimates from the second year were used because they represented more current population size and were more precise due to a greater percentage of marked raccoons. Also, population estimates were pooled across areas to allow for a more representative measure of density for

the overall study area. Seasonal estimates of density for 1982-83 were derived largely from J-S estimates. The fall density estimate was 1 raccoon/14.7 ha and included recruitment gain. Because J-S estimates were conservative and Jackknife estimates were more robust, these estimates were averaged within each area. These composite means were then averaged between areas to yield an appropriate summer density. Reflecting a pre-reproductive condition, the summer density was 1 raccoon/22.1 ha.

Density estimates for raccoons on CSWMA were compared with estimates from other areas (Table 9). These comparisons must be interpreted with caution because of differences in techniques and seasons sampled. Estimates described fall (Butterfield 1944, Cunningham 1962, Urban 1970, Sonenshine and Winslow 1972, Lehman 1977, Woods 1978) or winter (Johnson 1970, Rabinowitz 1981, Conner et al. 1983, Moore 1983) densities, thus reflecting recruitment gains. Highest densities were found in swamp and marsh areas. Lowest densities reported, including Chuck Swan, were exhibited in upland forests with the exception of Sonenshine and Winslow (1972). The 1982 fall estimate at Chuck Swan was appreciably higher than a 1976 fall estimate (Woods 1978), but this was somewhat expected since no hunting had been permitted at Chuck Swan in 4-years. From the above, it appeared that the population had recovered from an apparent overharvest in 1978 (Nottingham et al. 1982). The fall estimate at CSWMA was also slightly higher than a 1980 estimate for Cades Cove (Rabinowitz 1981) and an estimate (1 raccoon/17.4 ha) from lake border habitat at Lake Barkley in western Tennessee (G. Baumgardner, pers. comm.).

Table 9. Raccoon densities reported from different areas of the United States (mark-recapture estimates only).

State	Density (Raccoon/ha)	Habitat Type	Source
Alabama	1/8.5	Bottomland hardwood	Johnson (1970:99)
Indiana	1/.45 - 1/2.8	Swampland	Lehman (1977)
Ohio	1/10.9 - 1/42.9	Upland hardwood	Butterfield (1944)
Florida	1/8.7	Bottomland hardwood, pine-oak	Conner et al. (1983)
Illinois	1/5.7	Marshland	Urban (1970)
South Carolina	1/4.0	Swampland	Cunningham (1962)
Tennessee			
CSWMA (1983)	1/22.1 ^a	Upland hardwood	This study
CSWMA ((1982)	14.7 ^b	"	"
CSWMA (1976)	1/27.5	Upland hardwood	Woods (1978:64)
Cades Cove	1/17	Upland hardwood	Rabinowitz (1981:22)
Shelby Forest	1/7.2	Bottomland hardwood	Moore (1983)
Virginia	1/5.7	Upland forest, farmland	Sonenshine and Winslow (1972)

^aMean estimate of both study areas for early summer.

^bMean estimate of both study areas for fall (inclusive of recruitment).

The above comparisons are important because estimates from similar habitats are lacking. From these broad comparisons, fall density of raccoons at Chuck Swan appeared to be comparable to other upland habitats in Tennessee, but pre-reproductive density after winter indicated a lower density despite no influence of hunting.

Factors Affecting Raccoon Visitation Rates to Scent-Stations

From July 1981 to June 1983 eighteen scent-station surveys were completed producing 144 scent-station line samples. Five survey attempts were cancelled. Four were rained out. One was cancelled due to vehicle breakdown. Ninety-seven percent of the 1440 stations prepared were operable while the remainder (n=44) were affected by weather (rain, freezing temperatures) and human interference. A wide range of mammals was detected at the stations. Besides raccoons, tracks of opossum, gray fox, red fox, dog, housecat, striped skunk (Mephitis mephitis), mink (Mustela vison), cottontail rabbit, white-tailed deer, woodchuck (Marmota monax), gray squirrel (Sciurus carolinensis), and various birds were recorded at scent-stations. The total number of visits and the overall visitation rate of these species are summarized in Appendix C.

The potential use of the scent-station method is restricted by the capability to identify and measure sources of variation in visitation rates (Griffith et al. 1981). Therefore, to evaluate fully the relationship between raccoon visitation rates and population abundance, different sources of variation were evaluated. Temporal

differences, weather and spatial influences and various components of habitat were examined to determine their effects on visitation rates.

Temporal Variation

Over 2-years, raccoons visited scent-stations 70 times, producing a mean monthly visitation rate of 5.25%. Combined area measures indicated that monthly visitation by raccoons was erratic (Figure 7). Monthly visitation often differed between years. April surveys between years exhibited the lowest and highest visitation obtained during the study. September and June also indicated contrasting measures between years with indices differing by a factor of at least 2.7. Differences in consecutive months indicated a tenfold increase from April to May 1983.

Conner et al. (1983) reported no statistical differences in visitation rates between months across 2 years. The design of the above study was similar to that in the present study although scent-stations were located along trails. In West Tennessee, M. Kennedy and P. Leberg (Memphis State Univ., unpublished data) observed variation between monthly surveys although differences were not as distinct as those in the present study. Kennedy and Leberg used a different methodology for establishing scent-station locations which optimized raccoon visitation.

Scent-station surveys may reflect both population abundance and activity patterns of mammals (Griffith et al. 1981). In the present study, several monthly surveys recorded raccoon visitation

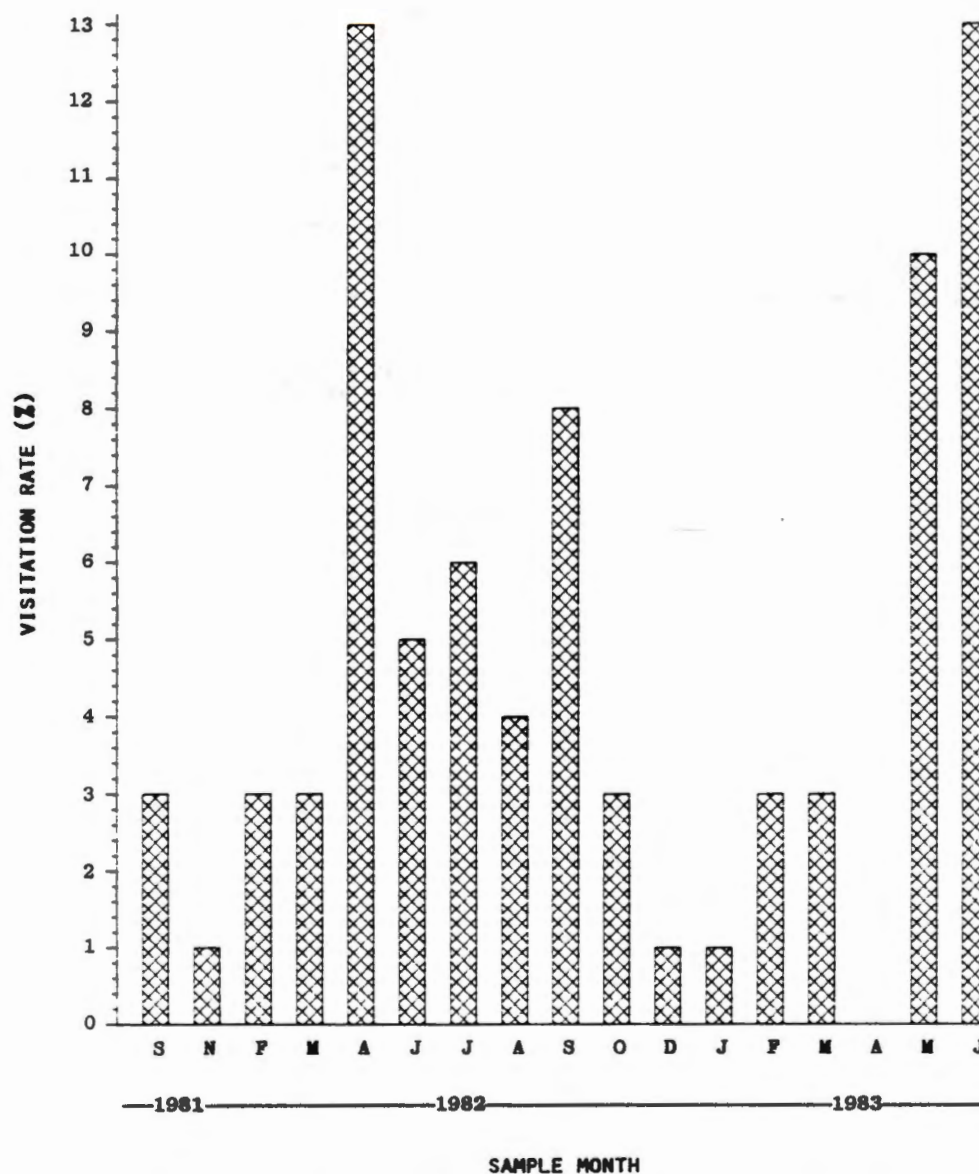


Figure 7. Monthly visitation rates of raccoons to scent-stations in both areas combined, CSWMA, 1981-83.

resulting from breeding and dispersal of raccoons. High visitation in April 1982 (Figure 7) was likely due to increased activity by adult male raccoons whose breeding activity peaked during that month. Capture success in both years (Figure 3, p. 28) increased from March to April, and this may be related to breeding activity. High visitation in May and June 1983 was largely due to increased activity by juvenile raccoons. Higher percentages of Class 1 raccoons were captured in May and June than in preceding and following months indicating dispersal of yearlings had occurred and contributed to high visitation at this time.

Seasonal measures of visitation (Table 10) were calculated by grouping monthly surveys as follows: winter, December-February; spring, March-May; summer, June-August; and fall, September-November. With both study areas combined, seasonal visitation ranged from 7.5% in summer to 2.6% in winter. The most notable difference between consecutive seasons occurred from winter (2.6%) to spring (6.3%). Standard deviations showed that the lowest variability in visitation rates occurred in winter with the other seasons indicating generally high variation. Overall trends in seasonal visitation were similar for the two study areas. In general, seasonal visitation by raccoons corresponded to monthly capture success of raccoons with the highest values occurring in summer, the lowest values in winter and intermediate values during spring and fall. These similarities were not surprising considering that both raccoon visitation and capture success reflected raccoon activity.

Table 10. Seasonal visitation rates (%) of raccoons to scent-stations on CSWMA, 1981-83.

	Season ^a			
	Fall	Winter	Spring	Summer
Control Area	5.6 (.11) ^b	2.6 (.06)	7.0 (.09)	8.8 (.12)
Experimental Area	3.2 (.06)	2.6 (.06)	5.7 (.07)	6.2 (.05)
Areas combined	4.4 (.08)	2.6 (.06)	6.3 (.10)	7.5 (.08)

^aFall = Sept.-Nov., Winter = Dec.-Feb., Spring = Mar.-May, Summer = Jun.-Aug.

^bStandard deviation of rate.

Differences in visitation rates among seasons and between years for both areas combined were tested by ANOVA. To analyze differences between years, the division for the second biological year was made in September 1982 because most young-of-the-year raccoons did not begin to range from their natal dens until late August and early September (Table 5, p. 43). Seasonal visitation rates were not similar for both years ($F=2.99$, $P<.03$). This inconsistency precluded interpreting seasonal visitation for combined area rates for both years.

— Differences in visitation rates among seasons and between years were examined for each area separately because seasonal visitation rates differed between years when data from both areas were analyzed. Visitation rates by raccoons did not differ by season ($F=2.07$, $P=.12$; $F=1.35$, $P=.27$) or year ($F=1.71$, $P=.20$; $F=.02$, $P=.88$) on the control and experimental areas, respectively. Thus, visitation rates from each area differed little between years and among seasons. The above results contrast with the findings that seasonal visitation rates differed between years when data from both areas were evaluated; this discrepancy may be due to differences in sample sizes or unreliability of the technique.

Extremes in seasonal raccoon visitation during the present study were similar in some respects to those observed by Conner et al. (1983), and Kennedy and Leberg (unpublished data). Both studies found that lowest visitation rates by raccoons occurred

during winter. Visitation rates were highest in early fall in bottomland hardwood and pine-oak flatlands surveyed by Conner et al. (1983). Although seasonal differences in visitation were not found in the present study, the highest raccoon visitation occurred in summer. Kennedy and Leberg (unpublished data) found similar results but reasons for this similarity are likely different. In West Tennessee (M. Kennedy, pers. comm.) increased visitation in summer is due to recruitment of young-of-the-year raccoons. At Chuck Swan, young-of-the-year raccoons do not become mobile members of the population until late August. Higher visitation by raccoons at Chuck Swan in early summer months resulted from movements of dispersing yearlings.

Linear regression was used to determine if replication of scent-station surveys was a factor in raccoon visitation over the 2-year study. Results indicated this variable was not related ($F=.18$, $P=.68$) to raccoon visitation measures and that raccoons probably did not develop a behavioral conditioning to replications of monthly surveys.

Spatial Variation

Mean visitation rate of raccoons to scent-station lines ranged from 2.2% to 8.9% (Table 11); visitation rates by line did not differ significantly (ANOVA, $F=1.92$, $P=.07$). Lines 3 ($\bar{x}=6.2$) and 4 ($\bar{x}=8.9$) exhibited the highest visitation; these lines were located in the Henegar Bend and Mossy Springs-Lindamood areas, respectively. These areas, which are adjacent, recorded

Table 11. Raccoon visitation rates by scent-station lines on the two study areas, CSWMA, 1981-83.

Control Area		Experimental Area	
Line Number	Visitation Rate (%)	Line Number	Visitation Rate (%)
1	2.8	5	2.8
2	2.2	6	5.8
3	6.2	7	3.9
4	8.9	8	4.0
Mean Visitation Rate = 5.03		Mean Visitation Rate = 4.13	

distinctively higher numbers of raccoon captures than other parts in CSWMA and suggested this combined area supported a high abundance of raccoons. A post hoc linear contrast was conducted testing differences between visitation rates on Lines 3 and 4 against visitation rate from other lines combined. Visitation rates in the Henegar Bend-Mossy Springs-Lindamood area were significantly higher ($F=10.2$ vs. Scheffe $F=3.8$, $P<.05$) (Neter and Wasserman 1974:478) than the combined visitation rate of the other lines in the study area; this indicated that scent-station lines in an area of high raccoon density recorded higher visitation than lines in areas with lower density.

The mean visitation of the 4 survey lines in the control area was 5.03%, compared to 4.13% in the experimental area. No significant difference in the mean visitation of lines in each area occurred as indicated by a planned comparison ($F=.75$, $P=.39$).

The precision of scent-station surveys could be improved by sampling in a period when spatial variation of visitation rates is least (Griffith et al. 1981). Of interest in this regard was the evaluation of line visitation by season in a 2-way ANOVA. Visitation rates by line did not vary significantly ($F=2.45$, $P=.07$) between seasons. From this result it appeared no gain in precision would be achieved by sampling in one specific season.

Variation Due to Weather

The influence of temperature was analyzed for its effect on raccoon visitation. Minimum temperature during the night of

the survey was positively related ($F=4.58$, $P<.04$) to visitation response by raccoons. The amount of visitation response explained in this model by minimum temperature was 22%. A minimum temperature (-2.7°C) depressed raccoon activity on 20 April 1983; thus, a replicate survey was conducted a week later during moderated temperatures. No change in visitation rate was observed, suggesting that minimum temperature probably had not resulted in depressed visitation. Visitation rates were not related ($F=2.6$, $P=.12$) to maximum temperatures during the day the survey was prepared. The above results suggested that temperature had little influence on raccoon visitation.

Wind and precipitation were similar for surveys throughout the study. The inherent design of this technique requires that precipitation should not occur during operation of the survey. However, precipitation data 24-hours prior to survey operation was collected because earlier scent-station research in Cades Cove suggested that precipitation and weather front activity prior to surveys appeared to influence raccoon visitation (K. Johnson, pers. comm.). In the present study precipitation prior to surveys probably had little effect on raccoon visitation because only a trace of rainfall was recorded prior to one survey.

Habitat Components Affecting Visitation Rates

Forest overstory, understory, and topographic location were analyzed by FUNCAT to examine visits in categories of habitat

characteristics at scent-station sites. Differences between categories were used to indicate potential influences of habitat components on visitation rates of raccoons.

Overstory component. Raccoons did not visit scent-stations according to overstory type. Visitation rates by raccoons were not significantly different between oak and mixed hardwood forests ($\chi^2=1.55$, $P=.21$; Model 1, Table 12).

No differences in raccoon visitation rates occurred between scent-stations with forest cover and stations with no forest cover ($\chi^2=1.42$, $P=.23$; Model 2, Table 12).

Understory component. Raccoons did not visit scent-stations according to understory type. Raccoon visitation rates did not vary between pine, poplar, and mixed hardwood understory types ($\chi^2=.14$, $P=.93$; Model 3, Table 12).

Topographic location and water distribution components. Visitation rates by raccoons did not differ between stations in upland and bottomland areas when analyzed with overstory ($\chi^2=.76$, $P=.38$; Model 1, Table 12) and understory classifications ($\chi^2=.16$, $P=.69$; Model 3, Table 12). Models 1 and 3 were re-analyzed with topographic location categorized by the distribution of water (present or absent). Raccoon visitation rates were not significantly ($\chi^2=.06$, $P=.81$; $\chi^2=.74$, $P=.39$) affected by the presence of water at scent-stations (Models 4 and 5, respectively, Table 12). Differences

Table 12. FUNCAT analyses of raccoon visitation to scent-stations on CSMMA, 1981-83, with respect to forest overstory type, forest presence, understory type, topographic location, and the presence of water.

Source of Variation	Categories of Habitat Components	Number of Cells in Factorial Design	Chi-square	Probability Level
<u>Model 1</u>		4		
Overstory type	Oak		1.55	.21
	Mixed hardwood			
Topographic location	Upland		.76	.38
	Bottomland			
Overstory type*			1.07	.30
Topographic location				
<u>Model 2</u>		3		
Forest presence	Forest		1.42	.23
	No forest			
Topographic location	Upland		.30	.58
	Bottomland			
Forest presence*			.35	.55
Topographic location				
<u>Model 3</u>		4		
Understory type	Pine		.14	.93
	Poplar			
	Mixed hardwood			
Topographic location	Upland		.16	.69
	Bottomland			
Understory type*			0	1.0
Topographic location				
<u>Model 4</u>		4		
Overstory type	Oak		.01	.94
	Mixed hardwood			
Topographic location	Creekside		.06	.81
	No water			
Overstory type*			.39	.53
Topographic location				
<u>Model 5</u>		3		
Understory type	Pine		.04	.83
	Poplar			
	Mixed hardwood			
Topographic location	Creekside		.74	.39
	No water			
Understory type*			0	1.0
Topographic location				

in topographic location may have been obscured by broad grouping of categories (upland and bottomland, Models 1 and 2). A trade-off between test reliability and resolution of the analysis occurred when two categories were selected to allow for an adequate number of visits in categories. Sample size in topographic categories was skewed toward upland stations (84%); this probably affected results in Models 1 and 2.

Visitation rates were not affected by the distribution of water. This finding contrasts with the widely held belief that water areas are attractive to raccoons. Allsbrook (1981) reported that raccoons used waterways extensively during all seasons in West Tennessee. High use of creeks by raccoons has been observed in mountain habitat in Cades Cove, GSMNP (A. Rabinowitz, pers. comm.). Not surprisingly, subsequent research in Cades Cove has shown significantly higher raccoon visitation to scent-stations near water (K. Johnson, unpublished data). Sumner and Hill (1980) believed that mid-winter scent-station surveys in upland areas were ineffective for recording visitation because of differential habitat use of aquatic areas during winter. Conner et al. (1983) also suggested that seasonal use of aquatic areas by raccoons lowered visitation rates to scent-stations in Florida. In the present study, trapping was more productive along creeks than in uplands, however explanation of why water did not affect raccoon visitation is unclear.

FUNCAT analyses were subject to biases in examining the effects of habitat features on visitation rates. Raccoon visitation

rates were assumed to be related to habitat components at scent-stations. Forest overstory composition at Chuck Swan is often heterogeneous, especially along roads. Habitat components outside of the sampled area may have attracted raccoons to the general area of scent-stations. The area sampled around stations varied somewhat based on the disturbance created by the construction of roads on which surveys were run. Also, features near scent-stations that were not measured (i.e., den sites, food availability) could have influenced visitation by raccoons.

Relationship of Scent-Station Visitation to Population Abundance

Evaluation of Visitation Rates and Population Size

Comparisons of seasonal visitation rates of raccoons and Jolly-Seber estimates of population size were made by area (Figures 8 and 9). Visitation rates by raccoons were calculated for the same time periods to which population estimates applied. Consistent trends in these measures were lacking on the control area (Figure 8). Some relationship between visitation rates and raccoon numbers was evident, however. A small increase occurred between the first and last visitation rates and corresponded to an increase in the population size during this period. In addition, visitation rates during Fall 1982 appeared to reflect a significant increase in population size.

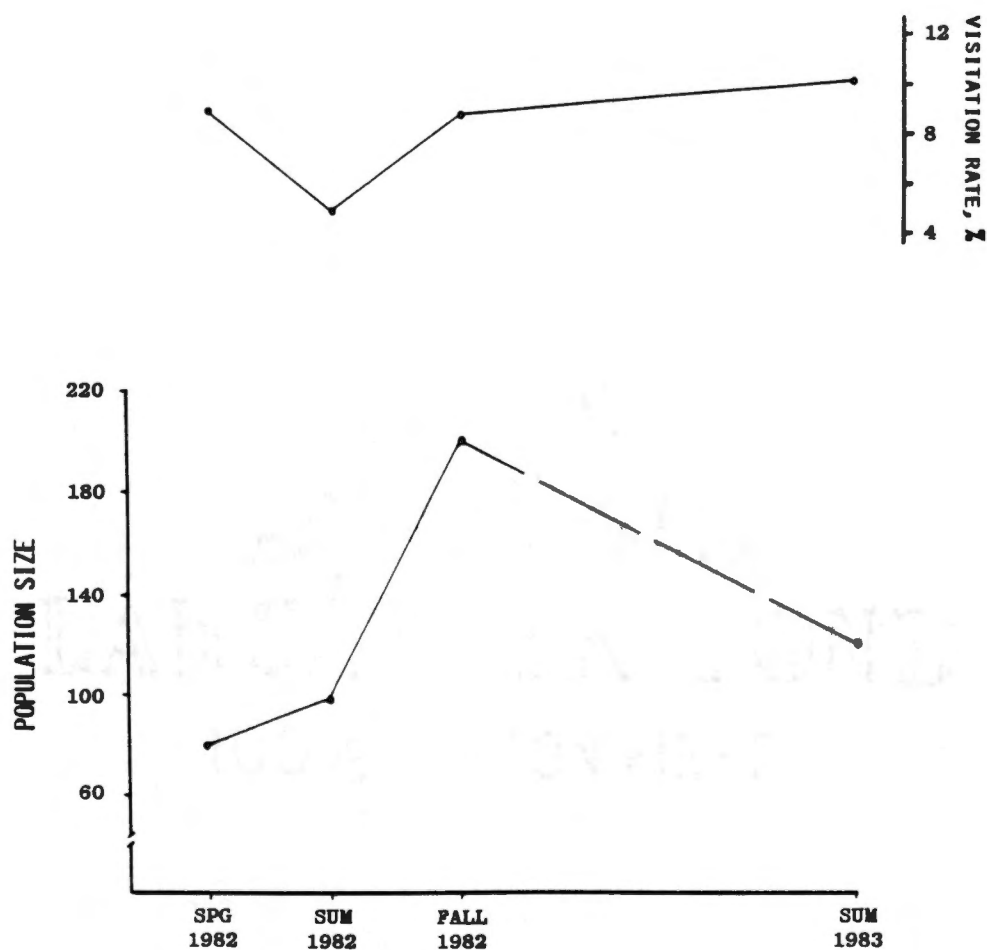


Figure 8. Comparison of seasonal estimates of population size (Jolly-Seber estimates) and visitation rates of raccoons on the control area, CSWMA, 1981-83.

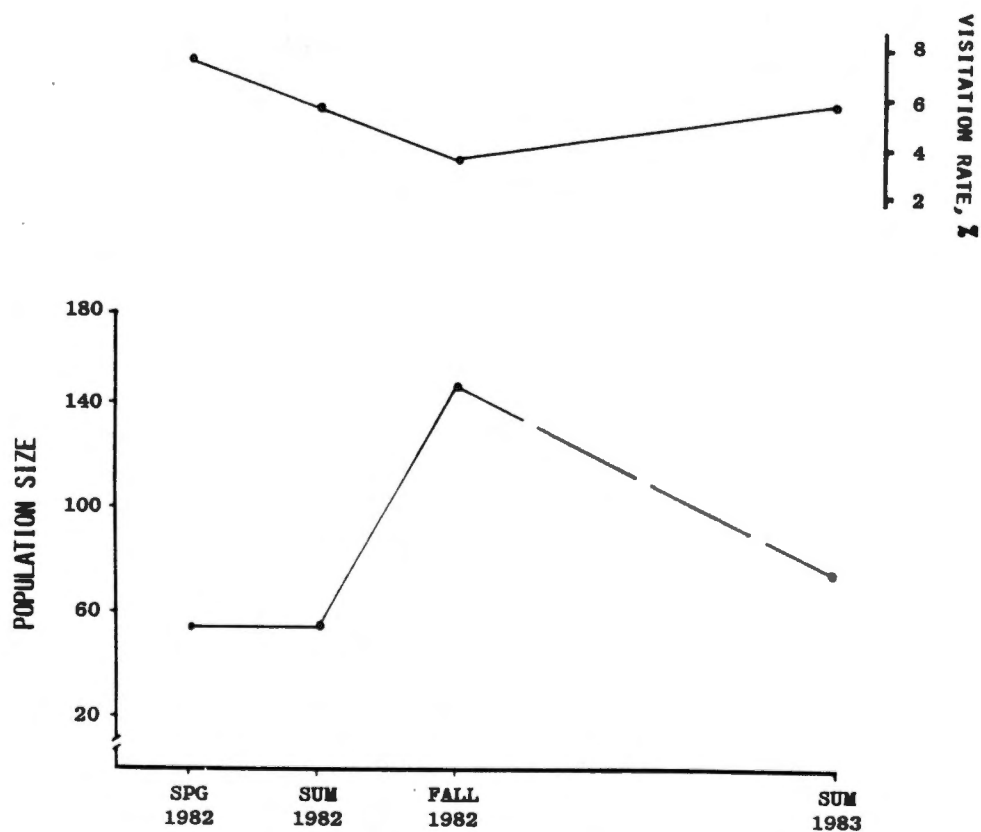


Figure 9. Comparison of seasonal estimates of population size (Jolly-Seber estimates) and visitation rates of raccoons on the experimental area, CSWMA, 1981-83.

Seasonal visitation rates and population estimates on the experimental area were inversely correlated (Figure 9). Visitation rates declined when a significant population increase occurred in Fall 1982. Different relationships between population size and visitation rates were observed for the 2 study areas despite similarities in seasonal trends of population size (Figure 6, p. 47) and visitation rates (Table 10, p. 64) between the study areas; this contrast may be due to differences in population size of the 2 areas (discussed later).

Evaluation of Visitation Rates and Trap Success

Two analyses were conducted to determine if visitation rates were related to trap success. Earlier results indicated some relationship between capture success and population size of raccoons. Raccoon visitation rates were not related ($F=.61$, $P=.44$) to capture success of raccoons (Figure 10).

A second analysis examined the relationship between visitation rates and capture success by given scent-station lines. It was believed that the number of individual raccoons captured near a given line broadly reflected raccoon abundance in the immediate areas. The total number of raccoons captured by area compared favorably to differences in population estimates with the control area having more raccoons than the experimental area (Table 13). The total number of visits on lines and the number of different raccoons caught near given survey lines were not related ($R=.54$, $P=.17$).

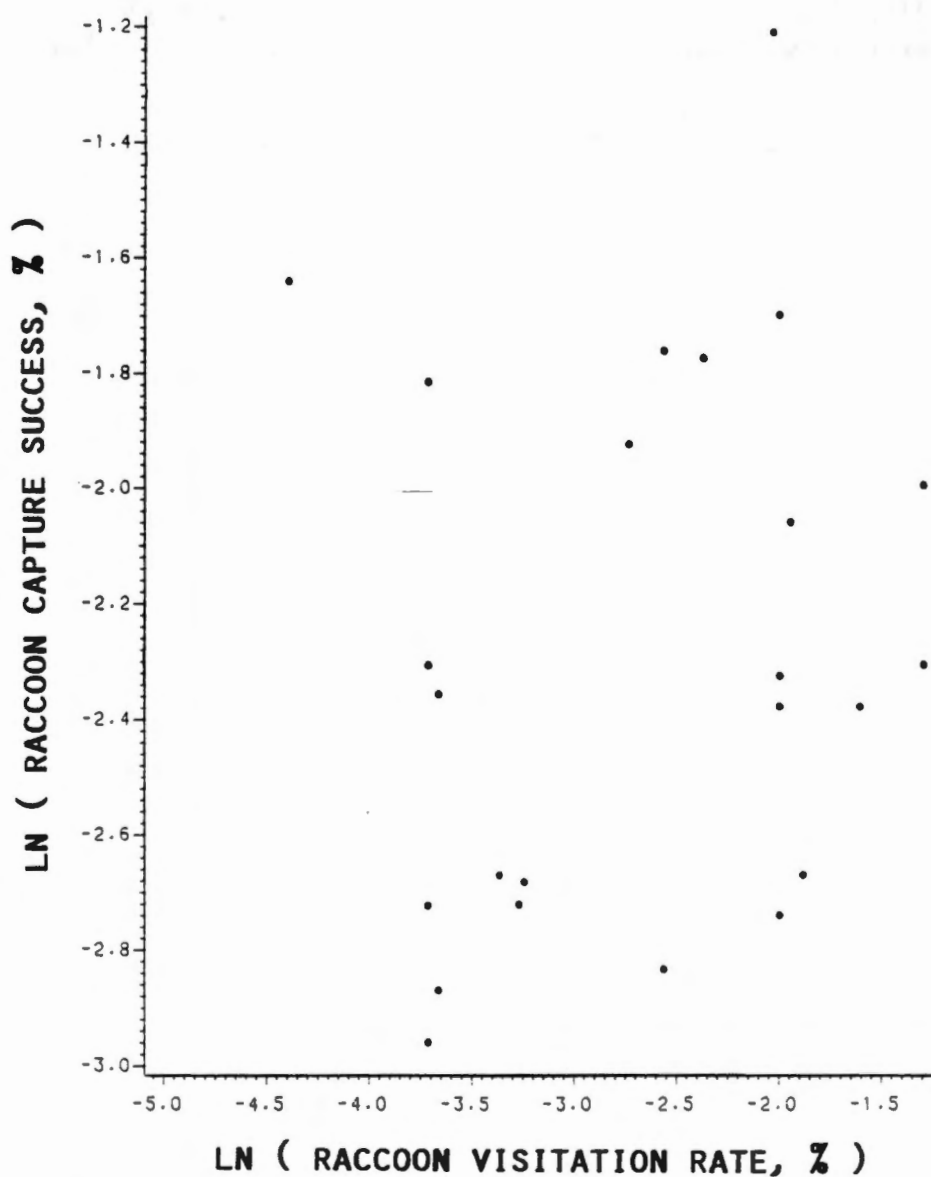


Figure 10. Graph of natural logarithms of visitation rates by raccoons with natural logarithms of percentage trapping success, on CSWMA, 1981-83.

Table 13. Total number of visits and captures of raccoons on scent-station lines on the two study areas, CSWMA, 1981-83.

Control Area			Experimental Area		
Line Number	Number Visits	Number Raccoon Captures ^a	Line Number	Number Visits	Number Raccoon Captures ^a
1	5	39	5	5	39
2	4	53	6	10	43
3	15	62	7	7	27
4	16	95	8	8	47
Totals	40	249		30	156

^aNumber of individual raccoons captured near given survey lines. Does not include recaptures of animals caught on a given line. However, animals were caught more than once among the different lines.

Summary and Assessment of Relationships Between Visitation Rates and Population Abundance

Results in this study indicated a poor relationship between visitation rates and estimates of population size. Area comparisons generally indicated few consistent patterns (Figures 8 and 9). In addition, population size and visitation rates were not correlated ($R=.12$, $P=.78$) when data from both areas were analyzed. Also, visitation rates of raccoons did not show consistent agreement with other general measures of raccoon abundance (i.e., capture success and total captures of raccoons).

Low visitation rates by raccoons may have precluded the ability of the scent-station survey to reflect differences in population size. Monthly visitation rates varied from 0 to 13% for both areas combined with an overall rate of 5.25%. No differences in annual visitation rates occurred between 1981-82 and 1982-83 on the control area although a 25% increase in the population size was revealed between years. Similarly, no differences in visitation rates between years were detected on the experimental area despite a 38% increase in annual population size. No differences between area visitation rates occurred although the control area showed a consistently higher number of raccoons. Roughton and Sweeny (1982) suggested that visitation rates of 40 to 60% were optimal for statistical evaluation of variation in visitation rates. Visitation rates of raccoons in the present study were considerably lower than the above measures.

Few studies have collected concurrent data on visitation rates and population size of raccoons to examine the relationship between these measures. Working in middle Tennessee, Rucker (1983) reported that low visitation rates by raccoons precluded measuring differences in raccoon populations; however, no estimates of raccoon density were obtained in this study. Linscombe et al. (1983) recorded visitation rates of raccoons in Louisiana over a 5-year period and found visitation rates ranging from 4.7 to 16.7% among 5 geographical regions. Regions with the highest harvests of raccoons exhibited the highest visitation rates of raccoons, however, annual variation in visitation rates hampered the assessment of the technique's reliability for reflecting population trends. Furthermore, Linscombe et al. (1983) did not compare raccoon visitation rates to population estimates of raccoons. In bottomland hardwood, Kennedy and Leberg (unpublished data) recorded visitation rates of raccoons that ranged from 20-80% during summer when raccoon densities were highest. Visitation rates by raccoons in upland habitat varied from 0-40% during summer. Raccoon densities in bottomlands were relatively high (1 raccoon/8 ha) and moderate (1 raccoon/16.2 ha) in uplands. These investigators believed that the technique was sensitive to population differences between habitats and to large changes in population abundance in bottomlands.

Results from the above studies may indicate that moderate levels of visitation improve the ability of this technique to detect variations in population size. Linscombe et al. (1983) recorded

relatively low (4.7-16.7%) visitation by raccoons but was unable to determine if population fluctuations were related to differences in visitation between years. In contrast, Kennedy and Leberg (unpublished data) were able to record large changes in raccoon numbers in habitats with high raccoon density when summer visitation rates ranged from 40 to 80%.

Two instances of a positive relationship between visitation rates and population abundance of raccoons occurred. Significantly higher visitation rates in the Henegar Bend and Mossy Springs-Lindamood areas were related to higher population abundance as measured by the total number of raccoons captured in these areas (Table 13). An increase in visitation rates between Summer and Fall of 1982 on the control area corresponded to a significant population increase. Common to each of these cases was high raccoon abundance suggesting that the technique may be sensitive to population abundance when raccoon density is high. If the above hypothesis is true, it may explain the lack of correspondence between population estimates and visitation rates on the experimental area which supported a smaller population than the control area.

Although the technique seemed sensitive to population differences in an area of high density of raccoons, it is likely that the overall density at CSWMA was a major factor in poor sensitivity of the method. Kennedy and Leberg (pers. comm.) hypothesized that the scent-station method, as applied in West Tennessee, began to lack sensitivity in reflecting population differences when raccoon

density was 1 raccoon/25 ha or lower. The lower range of raccoon density at CSWMA during the present study was similar to that mentioned above. Visitation rates recorded by Kennedy and Leberg (unpublished data) were higher than those in the present study and suggested a distinct influence by higher levels of visitation. This effect is valid from a statistical viewpoint considering that moderate visitation (40-60%) permits the optimal detection of quantitative change (Roughton and Sweeny 1982).

Management Implications

Management applications of the scent-station technique, as evaluated in this study, appear limited at this time. This assessment is especially applicable to east Tennessee since raccoon density in unprotected areas of east Tennessee is lower than that on CSWMA (Warr 1978, Minser and Pelton 1982). Visitation rates previously obtained from hunted areas in East Tennessee over the past 2 years are extremely low or zero (D. Scott, TWRA, unpublished data); these measures very likely lack sensitivity to detect real changes in raccoon populations.

Griffith et al. (1981) reported there are 2 broad sources of variation that affect coyote visitation to scent-stations. Variation can be derived from the methods used to prepare and maintain scent-stations, and from factors influencing animal response to scent-stations. Methodology subject to variation include sampling design, scent effectiveness, and observer bias. Factors influencing

animal response are largely ecological in nature, including sex, age, season, habitat, abundance, disturbance by humans, acclimation to scent, and lunar cycle. Johnson and Pelton (1981) reiterated the importance of the above design and ecological considerations in using scent-stations, and identified weather as an additional factor.

Design of scent-station surveys can incorporate factors that influence animal response to scent-stations. Morrison et al. (1981) demonstrated that the addition of lime to scent-stations increases visitation rates of bobcats. After 3 years of testing, Roughton (1982) selected FAS as a replacement attractant for increasing scent-station efficiency in monitoring coyotes. Kennedy and Leberg (unpublished data) utilized specific placement of scent-stations to increase visitation by raccoons in western Tennessee. Sumner and Hill (1980) suggested that scent-stations in upland areas were ineffective during winter because raccoons were using water areas in bottomlands during winter. The above examples illustrate the need to integrate the ecology of target species into scent-station surveys.

From the above, it appears the technique needs to be developed more specifically for raccoons in upland habitat of east Tennessee. Design of the scent-station survey (including station placement) in the present study was similar to that used by most southern states where the method is used for multi-species purposes. However, aspects of the ecology of the raccoon could be used to refine the technique's design. Development of the technique should focus on increasing

the number of raccoon visits to stations for optimizing visitation rates to the 40-60% range; this increase could permit more efficient statistical testing of visitation rates facilitating detection of population changes.

It is unknown whether refinements in the technique would adequately increase the technique's sensitivity for providing management data for raccoon populations. No accurate information exists concerning the allowable harvest of raccoons for maintaining a sustained yield in upland habitat. Nottingham et al. (1982) noted that an annual harvest of at least 31% of the raccoon population at Chuck Swan was too high to maintain sustained yields. Thus, modifications in the technique should increase raccoon visitation to a level where at least a 31% change in population size is detected.

CHAPTER V

SUMMARY AND CONCLUSIONS

1. A study investigating the relationship between visitation rates of raccoons to scent-stations and population size of raccoons on 2 study areas was conducted from 30 July 1981 through 3 July 1983 on the Chuck Swan Wildlife Management Area, Tennessee.

2. Livetrapping of raccoons was conducted to employ mark-recapture techniques for estimating population size on the 2 study areas. Both open (Jolly-Seber Model) and closed (Petersen Model, Models in program CAPTURE) population estimators were utilized. Open and closed estimates of population size were compared to evaluate model robustness and clarify bias in population estimates.

3. Scent-station surveys were operated concurrently with livetrapping. Four scent-station lines, each consisting of 10 scent-stations spaced at 0.32 km intervals, were activated monthly in each study area.

4. During 8,000 trapnights, 248 raccoons were captured a total of 649 times. A greater number of different raccoons were captured on the control area ($n=136$) than on the experimental area ($n=112$).

5. Capture success was adjusted by accounting for loss of traps sprung by all sources to avoid underestimates in capture success. Monthly capture success of raccoons differed significantly between months ($F=6.3$, $P<.0001$). Capture success ranged from 16.5% in summer

to 5.6% in winter. Capture success was 9.1% in the first year and 14.8% in the second year and appeared related to an increase in population size.

6. An increased proportion of yearling raccoons was found in late May and June during both years indicating dispersal of yearlings occurred at that time.

7. The sex ratio for all captured raccoons was 121 males per 100 females but was not significantly different from 1:1 ($\chi^2=2.5$, $P=.12$). A livetrapp bias favoring the capture of males was shown where males exhibited higher average number of captures than females ($T=2.94$, $P<.004$).

8. Little variation in juvenile:adult age ratios was indicated between years with juveniles comprising approximately 23% of the capture sample. Distribution of age classes between areas was not significantly different ($\chi^2=8.7$, $P=.08$) indicating that raccoons from both areas were actually components of one large population.

9. Longevity of raccoons at Chuck Swan was at least 9 years of age as indicated by the recapture of tagged raccoons from previous studies at Chuck Swan.

10. Both natural and unnatural causes of mortality were found in 15 documented cases of raccoon mortality. Five positive titers of canine distemper were found in raccoons indicating the Chuck Swan population was exposed to an outbreak of distemper, probably in spring 1982. However, epidemic proportions were probably not reached because population size in both areas increased in the second year of the study.

11. Specific interpretations of estimates of survival rates were complicated by survival rates measuring losses to both mortality and emigration. Survival rates were lowest in spring and fall seasons in both areas. Survival rates differed significantly ($P < .048$) between study areas in Spring 1982. Lower survival rates in the experimental area may have been due to greater emigration from this area which contained a longer boundary than the control area. Survival rates did not differ ($P = .10$) between areas in Fall 1982.

12. The breeding season of raccoons at Chuck Swan ranged from late February to late April with a peak in April. Most parturition occurred from mid-May to mid-June as determined by extrapolating birth dates of pre-weaned raccoons.

13. According to Jolly-Seber estimates, seasonal fluctuations in population size were similar in both study areas over the 2-year study. J-S estimates indicated significant increases of 112% and 171% from summer-fall, 1982, on the control and experimental areas, respectively. Jolly-Seber estimates in the control area were consistently higher than those in the experimental area. High turnover was suggested in a 45% population decrease (average from both areas) from Fall 1982 to Summer 1983. This decline occurred despite the absence of hunting. Emigration of raccoons from sampling areas was indicated in spring survival estimates; this may have contributed to observed population decreases from winter-spring to summer.

14. All closed model estimates indicated that the control area supported a denser raccoon population than the experimental

area. Few estimates from closed models were available for evaluating seasonal fluctuations in population size but Petersen estimates in the experimental area indicated a 54% increase in population size from 1982 to 1983.

15. Because heterogeneity of capture was demonstrated in capture probabilities of raccoons, the Jackknife estimator in CAPTURE provided robust estimates of population size in 1983. Jackknife estimates helped to assess bias in J-S estimates.

16. Fall J-S estimates from both areas were averaged in 1982 producing a density of 1 raccoon/14.7 ha; this measure included recruitment gain from young-of-the-year raccoons. Summer J-S estimates were averaged with Jackknife estimates to provide a summer density of 1 raccoon/22.1 ha in 1983. Fall density of raccoons at Chuck Swan compared similarly to other upland habitats of Tennessee.

17. From July 1981 to June 1983, 18 scent-station surveys were completed; 1,396 scent-stations were operable. Tracks of 12 species of mammals were recorded at scent-stations. Raccoons visited scent-stations 70 times producing a mean monthly visitation rate of 5.25%.

18. Monthly visitation rates by raccoons were low and erratic, with the same months often differing between years. Several monthly visitation measures were influenced by adult breeding activity and dispersal of yearlings.

19. Seasonal visitation rates ranged from 7.5% in summer to 2.6% in winter. Seasonal visitation rates for both areas combined

were not similar for both years, but differed little between years and among seasons when data were analyzed by area.

20. Mean visitation rates of raccoons to scent-station lines ranged from 2.2% to 8.9%; these rates were not significantly ($F=1.92$, $P=.07$) different among lines. Visitation rates by line were not significantly ($F=2.45$, $P=.07$) different between seasons suggesting that no gain in precision would be achieved by sampling in 1 specific season.

21. Minimum temperature during the night the survey was activated was positively related ($F=4.58$, $P<.04$) to raccoon visitation but the strength of this relationship was somewhat poor ($R^2=.22$). Other weather variables (maximum temperature, wind, and precipitation) did not affect raccoon visitation rates.

22. Influences of habitat components on raccoon visitation rates were analyzed by the FUNCAT procedure. Forest overstory type did not influence raccoon visitation ($\chi^2=1.55$, $P=.21$). Visitation rates of raccoons did not differ between forested and open canopy sites ($\chi^2=1.42$, $P=.23$). Understory type was not a factor in raccoons visiting scent-stations ($\chi^2=.14$, $P=.93$). Topographic location of scent-stations ($\chi^2=.76$, $P=.38$) and the presence of water at scent-stations ($\chi^2=.06$, $P=.81$) did not affect raccoon visitation rates.

23. No consistent trends between seasonal visitation rates and population size of raccoons were exhibited in graphic comparisons made by study area. Correlation analysis showed no relationship ($R=.12$, $P=.78$) between population size and seasonal visitation rates from both study areas.

24. Measures of trapping success of raccoons were evaluated with raccoon visitation rates. No relationship ($F=.61$, $P=.44$) occurred between capture success and visitation rates of raccoons. The total number of visits on lines and the number of different raccoons caught near respective survey lines were not related ($R=.54$, $P=.17$) and further indicated a lack of a relationship between visitation rates and population abundance of raccoons.

25. Only 2 cases of a positive relationship between visitation rates and population abundance were found. Common to each case, was high raccoon abundance which indicated that the technique may be sensitive to population abundance when raccoon density was high.

26. Although moderate raccoon density in this study hampered detection of population changes, low visitation rates by raccoons also were a large factor in visitation rates not reflecting changes in population abundance.

27. Management implications from this study suggest that the scent-station technique, as employed, is not reliable for monitoring raccoon populations in upland habitat of East Tennessee.

28. It is suggested that refinements in the technique focus on increasing visitation rates by designing the technique more specifically for raccoons.

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APPENDICES

LANCASTER BOND
100% COTTON FIBRE

APPENDIX A

Table 14. Capture records of raccoons trapped on CSMMA, 30 July, 1981 to 3 July, 1983.

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
101	76	77	30 July 1981	1	1	12	2	3	3.2
102	78	79	4 August 1981	1	3	22	2	2	3.4
102	78	79	12 June 1982	2	42	22	2	2	
103	80	81	4 August 1981	1	3	15	2	1	3.4
103	80	81	27 May 1982	2	53	18	2	2	
104	101	102	5 August 1981	1	4	6	1	1	3.1
105	82	83	5 August 1981	1	4	25	2	4	3.6
105	82	83	14 July 1982	2	54	23	2		3.2
106	2	1	2 September 1981	1	6	6	2	4	2.7
107	3	4	8 September 1981	1	7	1	2	2	3.2
108	6	5	9 September 1981	1	8	8	2	2	3.9
108	6	5	29 July 1982	2	64	3	2		
109	1	2	9 September 1981	1	8	26	1	2	4.1
109	1	2	28 February 1982	2	30	19	1	2	4.5
109	1	2	6 April 1982	3	26	29	1	2	
109	1	2	5 April 1983	4	83	15	1	3	
109	1	2	5 June 1983	5	96	14	1	3	4.1
109	1	2	9 June 1983	6	100	20	1	3	
110	3	4	9 September 1981	1	8	15	1	3	3.9
111	5	6	9 September 1981	1	8	22	1	2	3.6
111	5	6	4 April 1982	2	24	23	1	2	
111	5	6	22 April 1982	3	34	24	1	2	
111	5	6	3 May 1982	4	38	22	1	2	
111	5	6	25 June 1982	5	46	22	1	2	
111	5	6	8 July 1982	6	50	23	2	2	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
112	8	7	10 September 1981	1	9	11	1	2	3.6
112	8	7	17 September 1981	2	12	14	1	2	
112	8	7	24 February 1982	3	28	12	1	2	5.0
113	9	10	10 September 1981	1	9	16	1	2	3.7
113	9	10	29 September 1981	2	14	14	1	2	
114	11	12	15 September 1981	1	10	14	1	2	4.7
114	11	12	14 May 1982	2	44	16	1	2	
114	11	12	20 May 1982	3	50	11	1	2	
114	11	12	27 May 1982	4	53	17	1	2	
114	11	12	28 May 1982	5	54	14	1	2	
114	11	12	29 May 1982	6	55	16	1	2	
114	11	12	1 June 1982	7	58	14	1	2	
114	11	12	5 June 1982	8	59	14	1	2	
114	11	12	6 June 1982	9	60	17	1	2	
114	11	12	26 July 1982	10	61	16	1	2	
114	11	12	28 July 1982	11	63	14	1	2	
114	11	12	29 July 1982	12	64	17	1	2	
114	11	12	30 July 1982	13	65	16	1	2	
114	11	12	31 July 1982	14	66	14	1	2	
114	11	12	2 August 1982	15	68	17	1	2	
114	11	12	21 August 1982	16	73	11	1	2	
114	11	12	22 August 1982	17	74	8	1	2	
114	11	12	23 August 1982	18	75	11	1		
114	11	12	2 May 1983	19	92	16	1		
114	11	12	16 May 1983	20	95	17	1		

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
114	11	12	6 June 1983	21	97	17	1		
114	11	12	7 June 1983	22	98	18	1		
115	13	14	17 September 1981	1	12	23	1	2	3.6
115	15	14	1 October 1981	2	16	21	1	2	
115	15	14	13 April 1982	3	30	21	1	2	
115	15	14	1 October 1982	4	70	22	1	2	
115	253	14	18 April 1983	5	89	5	1	3	3.2
115	253	254	14 May 1983	6	93	21	1	3	
116	7	8	17 September 1982	1	12	5	2	1	2.1
116	7	8	29 September 1981	2	14	5	2	1	3.2
116	7	8	10 April 1983	3	84	4	2	2	
117	10	9	29 September 1981	1	14	9	2	2	4.6
117	10	9	28 July 1982	2	63	10	2	2	
117	10	9	14 May 1983	3	93	9	2	3	2.7
118	16	17	1 October 1981	1	16	3	1	1	2.7
119	11	12	1 October 1981	1	16	9	2	1	2.7
119	11	12	16 October 1981	2	6	29	2	1	
119	11	12	29 July 1982	3	64	8	2	2	
119	11	12	24 August 1982	4	76	19	2	2	
120	20	21	9 October 1981	1	2	32	1	3	3.9
120	142	21	3 May 1982	2	38	32	1	3	
120	142	21	3 April 1983	3	81	32	1	3	
120	142	21	8 June 1983	4	99	32	1	3	
121	22	23	14 October 1981	1	4	32	1	4	4.2
121	22	23	12 April 1982	2	29	33	1	4	4.3

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
121	22	23	18 April 1983	3	89	31	1	4	
121	22	23	16 May 1983	4	95	32	1	4	
122	13	14	15 October 1981	1	5	37	2	1	2.3
122	13	14	4 October 1982	2	73	37	2	2	
123	24	25	16 October 1981	1	6	38	1	1	2.3
124	26	27	23 October 1981	1	7	29	1	3	5.4
124	26	27	23 March 1982	2	40	44	1	3	3.6
125	16	15	10 November 1981	1	18	22	2	2	4.1
125	16	15	1 May 1983	2	91	22	2	2	
126	28	29	10 November 1981	1	9	7	1	2	5.4
126	28	29	11 March 1982	2	36	15	1	2	
126	28	29	11 June 1982	3	41	15	1	2	
126	28	29	15 May 1983	4	94	30	1	2	
126	28	29	9 June 1983	5	100	15	1	2	
127	30	31	10 November 1981	1	9	37	1	1	3.5
127	30	31	2 December 1981	2	20	37	1	1	
127	30	31	31 May 1982	3	57	14	1	2	
128	32	33	12 November 1981	1	11	31	1	4	5.9
129	19	20	12 November 1981	1	11	29	2	3	5.4
129	67	20	5 May 1982	2	40	29	2	3	3.6
129	67	20	18 July 1982	3	58	29	2	3	
129	67	20	3 April 1983	4	81	29	2	3	
129	236	237	8 June 1983	5	99	29	2	3	3.6
130	21	22	12 November 1981	1	11	29	2	1	3.5
131	34	35	17 November 1981	1	20	15	1	3	6.4

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
131	34	35	22 February 1982	2	26	18	1	3	6.1
131	34	35	19 April 1982	3	32	26	1	3	5.0
131	34	35	15 June 1982	4	45	23	1	3	
131	34	35	16 July 1982	5	56	23	1	3	
131	34	35	10 April 1983	6	84	27	1		
131	34	35	1 May 1983	7	91	23	1		
131	34	35	8 July 1983	8	99	27	1		
132	23	24	17 November 1981	1	20	13	2	1	3.2
132	23	24	21 March 1982	2	38	12	2	1	
132	23	24	14 May 1982	3	44	12	2	1	
132	23	24	1 May 1983	4	91	12	2	2	
133	25	26	17 November 1981	1	20	11	2	3	4.5
134	27	28	17 November 1981	1	13	36	2	3	4.5
134	27	28	22 April 1982	2	34	36	2	3	
134	215	28	12 April 1983	3	86	37	2	3	2.3
134	215	28	5 June 1983	4	96	36	2	3	
135	29	30	19 November 1981	1	15	38	2	2	4.5
135	29	30	1 October 1982	2	70	37	2	2	
136	36	37	19 November 1981	1	15	31	1	2	5.9
137	38	39	24 November 1981	1	17	39	1	3	6.8
137	171	39	17 June 1982	2	44	62	1	4	4.5
137	171	39	5 June 1983	3	96	34	1	4	
138	31	32	24 November 1981	1	17	33	2	3	5.0
138	31	32	15 June 1982	2	45	33	2	3	3.2
138	31	32	9 June 1983	3	100	33	2		

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
139	41	40	25 November 1981	1	18	30	1	3	5.9
140	42	43	25 November 1981	1	18	34	1	3	5.5
141	33	34	10 December 1981	1	3	70	2	4	4.5
141	33	34	3 May 1982	2	38	66	2	5	
142	44	45	10 December 1981	1	1	65	1	1	4.5
142	44	45	19 July 1982	2	59	61	1	1	
142	44	45	3 August 1982	3	65	47	1	1	
142	44	45	14 August 1982	4	67	45	1	1	
142	44	45	13 June 1983	5	81	59	1	2	
142	44	45	15 June 1983	6	83	63	1	2	
142	44	45	24 June 1983	7	92	62	1	2	
143	35	36	15 December 1981	1	6	70	2	3	4.6
143	35	36	18 June 1982	2	45	70	2	3	
143	35	36	27 June 1983	3	95	66	2	3	
144	46	47	15 December 1981	1	4	67	1	2	6.8
144	46	47	24 January 1982	2	13	68	1	2	
144	46	47	2 April 1982	3	22	73	1	2	
144	46	47	14 June 1982	4	44	40	1	2	
144	46	47	17 June 1983	5	84	68	1		
145	48	49	30 December 1981	1	8	53	1	4	7.0
145	48	49	28 January 1982	2	16	76	1	4	5.5
145	48	49	24 February 1982	3	29	48	1	4	
146	37	38	31 December 1981	1	7	60	2	4	4.3
146	37	38	28 May 1982	2	54	60	2	4	
146	37	38	15 June 1982	3	42	74	2	4	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
146	37	38	13 June 1983	4	81	74	2		
146	37	38	14 June 1983	5	82	60	2		
146	37	38	27 June 1983	6	95	74	2		
147	39	40	1 January 1982	1	6	73	2	2	5.0
147	39	40	19 June 1983	2	87	73	2	2	
148	50	51	2 January 1982	1	8	46	1	2	5.9
148	50	51	11 June 1982	2	41	39	1	2	
148	50	196	17 August 1982	3	68	45	1	2	3.2
149	52	53	23 January 1982	1	12	65	1	5	6.1
149	52	53	28 January 1982	2	16	61	1	5	
149	52	53	15 June 1982	3	42	61	1	5	
150	41	42	23 January 1982	1	12	79	2	1	3.9
150	41	42	23 February 1982	2	28	55	2	1	
150	41	42	30 July 1982	3	61	54	2	1	
151	54	55	24 January 1982	1	13	46	1	3	5.5
151	54	55	12 April 1982	2	29	29	1	3	
151	54	55	22 April 1982	3	34	30	1	3	
151	54	55	20 July 1982	4	60	30	1	3	4.1
151	54	55	17 April 1983	5	88	19	1	3	
151	54	55	1 May 1983	6	91	29	1	3	
151	54	55	9 June 1983	7	100	36	1	3	
152	56	57	24 January 1982	1	13	51	1	1	2.3
153	58	59	24 January 1982	1	13	53	1	3	5.5
154	43	44	24 January 1982	1	13	80	2	3	3.9
155	60	61	26 January 1982	1	14	80	1	1	2.3

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
156	62	63	26 January 1982	1	13	59	1	2	5.0
156	62	63	3 March 1982	2	32	46	1	2	
156	62	63	15 May 1982	3	45	46	1	2	
156	62	161	28 May 1982	4	54	59	1	2	4.1
156	62	189	31 July 1982	5	62	46	1	2	4.5
156	62	189	15 June 1983	6	83	45	1		
156	62	189	2 July 1983	7	99	46	1		
157	64	65	27 January 1982	1	15	65	1	2	5.5
157	64	65	6 July 1982	2	48	66	1	2	
157	64	65	15 July 1982	3	55	66	1	2	
157	64	65	8 September 1982	4	63	63	1	2	
157	64	65	2 July 1983	5	99	63	1		
158	66	67	29 January 1982	1	17	48	1	3	4.5
158	66	67	3 March 1982	2	33	48	1	3	3.6
158	66	67	17 May 1982	3	47	58	1	3	
158	66	67	28 May 1982	4	54	48	1	3	
158	66	67	1 August 1982	5	63	58	1	3	
158	66	67	3 August 1982	6	65	58	1	3	
158	66	67	19 August 1982	7	70	58	1	3	
158	66	67	14 June 1983	7	82	58	1		
158	66	67	19 June 1983	8	87	58	1		
158	66	67	1 July 1983	9	98	57	1		
159	70	71	29 January 1982	1	16	60	1	4	5.5
159	70	71	5 May 1982	2	40	61	1	4	
159	186	71	16 July 1982	3	56	74	1	4	4.5

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
159	186	71	17 June 1983	4	85	61	1	4	
159	293	71	19 June 1983	5	87	63	1	4	3.2
160	72	73	29 January 1982	1	16	73	1	5	5.5
160	72	73	6 April 1982	2	26	73	1	5	
161	74	75	29 January 1982	1	17	56	1	3	5.9
161	74	170	16 June 1982	2	43	62	1	3	5.9
161	74	170	13 July 1982	3	53	63	1	3	
162	76	77	4 February 1982	1	19	52	1	4	5.0
163	78	80	10 February 1982	1	23	18	1	3	5.5
163	107	108	23 March 1982	2	40	18	1	3	4.0
163	107	108	8 April 1982	3	28	27	1	3	
163	107	108	15 June 1982	4	45	26	1	3	
163	107	108	10 April 1983	5	84	23	1		
164	46	45	17 February 1982	1	24	60	2	1	4.1
164	46	45	21 February 1982	2	26	18	2	1	
164	46	45	4 March 1982	3	34	60	2	1	
164	46	45	22 June 1983	4	90	63	2	2	
165	81	82	20 February 1982	1	25	44	1	2	4.3
166	83	84	21 February 1982	1	26	47	1	5	3.9
167	85	86	23 February 1982	1	28	52	1	1	4.1
167	85	86	14 June 1982	2	41	68	1	1	
167	85	86	15 June 1983	3	83	73	1	2	
167	85	86	23 June 1983	4	91	73	1	2	
168	87	88	24 February 1982	1	29	18	1	4	5.2
169	89	90	24 February 1982	1	29	44	1	2	3.9

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
170	47	48	25 February 1982	1	29	15	2	2	2.7
171	91	92	25 February 1982	1	29	7	1	1	3.4
171	91	92	16 May 1982	2	46	7	1	1	
171	91	92	19 May 1982	3	49	7	1	1	
171	91	92	5 June 1982	4	59	7	1	1	
172	95	96	28 February 1982	1	30	20	1	3	5.5
172	95	96	12 March 1982	2	37	43	1	3	
172	95	96	17 May 1982	3	47	45	1	3	
172	95	96	20 May 1982	4	50	19	1	3	
172	95	96	6 June 1982	5	59	43	1	3	4.7
172	95	96	30 April 1983	6	90	8	1		5.0
172	95	96	16 May 1983	7	95	11	1		
173	49	50	11 March 1982	1	36	51	2	3	5.0
173	49	50	18 June 1983	2	86	50	2	3	
173	49	50	21 June 1983	3	89	49	2	3	
174	99	100	22 March 1982	1	39	48	1	2	4.1
174	99	100	12 May 1982	2	42	48	1	2	
174	99	100	15 May 1982	3	45	44	1	2	4.1
174	99	100	20 May 1982	4	50	50	1	2	
174	99	100	14 June 1983	5	82	48	1		
174	99	100	19 June 1983	6	87	48	1		
174	99	100	20 June 1983	7	88	50	1		
174	99	100	22 June 1983	8	90	52	1		
174	99	100	25 June 1983	9	93	51	1		
174	99	100	27 June 1982	10	95	49	1		

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
174	99	100	28 June 1983	11	96	50	1		
174	99	100	2 July 1983	12	99	44	1		
174	99	100	3 July 1983	13	100	48	1		
175	103	104	22 March 1982	1	39	51	1	3	4.1
176	105	106	22 March 1982	1	39	18	1	2	3.6
176	105	106	12 June 1982	2	42	27	1	2	
176	105	106	26 June 1982	3	47	28	1	2	
176	105	106	18 April 1983	4	89	27	1		
176	105	106	6 June 1983	5	97	27	1		
177	109	110	1 April 1982	1	21	21	1	3	3.2
177	109	110	12 April 1982	2	29	25	1	3	
177	109	110	13 June 1982	3	43	25	1	3	
177	109	110	15 June 1982	4	45	22	1	3	
178	111	112	1 April 1982	1	21	24	1	3	4.5
178	111	112	19 April 1982	2	32	25	1	3	
178	111	112	12 June 1982	3	42	25	1		
178	111	112	14 June 1982	4	44	21	1	3	
178	111	112	26 June 1982	5	47	23	1	3	
179	115	116	1 April 1982	1	21	35	1	3	4.1
179	115	116	8 April 1982	2	28	38	1	3	
179	115	116	15 June 1982	3	45	36	1	3	
179	115	116	15 July 1982	4	55	37	1	3	
179	115	116	17 July 1982	5	57	35	1	3	
180	113	114	1 April 1982	1	21	35	1	4	4.5
180	113	114	3 April 1982	2	23	36	1	4	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
180	113	114	5 April 1982	3	25	38	1	4	
180	113	114	8 April 1982	4	28	36	1	4	
180	113	114	12 April 1982	5	29	35	1	4	
180	113	114	20 April 1982	6	33	38	1	4	
180	113	137	22 April 1982	7	34	37	1	4	4.1
180	113	137	3 May 1982	8	38	37	1	4	
180	113	172	7 July 1982	9	49	35	1	4	4.3
180	113	172	5 April 1983	10	83	37	1	4	
180	113	172	12 April 1983	11	86	38	1	4	
180	113	172	15 May 1983	12	94	38	1	4	
181	117	118	1 April 1982	1	21	62	1	2	3.2
181	117	118	14 May 1983	2	93	34	1	2	
182	119	120	2 April 1982	1	22	80	1	4	4.3
183	51	52	3 April 1982	1	23	27	2	2	4.1
183	51	52	14 June 1982	2	44	23	2	2	
184	53	54	3 April 1982	1	23	35	2	5	3.4
185	55	56	3 April 1982	1	23	39	2	1	3.0
185	55	56	9 July 1982	2	51	39	2	1	
185	55	56	12 April 1983	3	86	39	2	2	
186	121	122	4 April 1982	1	24	25	1	2	4.8
186	121	122	14 June 1982	2	44	25	1	2	
186	121	122	10 October 1982	3	76	21	1	2	
186	121	122	8 June 1983	4	99	25	1		
187	123	124	4 April 1982	1	24	32	1	2	3.9
187	123	124	9 July 1982	2	51	31	1	2	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
188	125	126	4 April 1982	1	24	80	1	3	3.0
188	125	126	10 July 1982	2	52	77	1	3	
188	125	126	17 July 1982	3	57	75	1	3	
188	125	126	21 June 1983	4	89	79	1		
188	125	126	25 June 1983	5	93	54	1		
188	125	126	29 June 1983	6	97	55	1		
188	125	126	2 July 1983	7	99	78	1		
189	127	128	5 April 1982	1	25	37	1	2	3.6
189	127	128	11 June 1982	2	41	36	1	2	
189	127	128	2 May 1983	3	92	35	1		
189	127	128	14 May 1983	4	93	35	1		
189	129	128	8 June 1983	5	99	35	1		
190	129	130	5 April 1982	1	25	40	1	2	3.9
190	129	130	13 April 1982	2	30	65	1	2	
190	129	130	17 June 1982	3	44	62	1	2	
190	57	130	11 April 1983	4	85	8	1		
191	59	58	15 April 1982	1	31	36	2	4	3.2
192	59	60	15 April 1982	1	31	22	2	2	2.7
192	61	60	8 July 1982	2	50	22	2	2	
193	61	62	19 April 1982	1	31	63	2	4	3.9
193	61	62	1 May 1982	2	36	61	2	4	
193	61	62	7 July 1982	3	49	62	2	4	
193	61	62	19 July 1982	4	59	63	2	4	
193	61	62	17 September 1982	5	67	61	2	5	
193	61	62	15 June 1983	6	83	61	2	5	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
193	61	62	19 June 1983	7	87	62	2	5	
193	61	62	1 July 1983	8	98	62	2	5	
194	63	64	20 April 1982	1	32	66	2	3	4.1
195	131	132	20 April 1982	1	33	25	1	1	3.9
196	133	134	20 April 1982	1	33	39	1	2	4.1
196	133	134	19 July 1982	2	59	30	1	2	
196	133	134	16 April 1983	3	87	32	1		
196	133	134	5 June 1983	4	96	31	1		
197	65	66	22 April 1982	1	34	25	2	1	2.3
199	65	66	16 April 1983	2	87	25	1	2	
198	135	136	22 April 1982	1	34	26	1	2	4.3
198	135	136	30 April 1982	2	35	30	1	2	
198	135	136	12 May 1982	3	42	56	1	2	
198	135	136	21 May 1982	4	51	57	1	2	
198	135	136	31 May 1982	5	57	17	1	2	
198	135	136	15 June 1982	6	45	30	1	2	
198	135	136	7 September 1982	7	62	30	1	2	
198	135	136	8 June 1983	8	99	39	1		
198	135	136	9 June 1983	9	100	39	1		
198	135	136	15 June 1983	10	83	48	1		
198	135	136	16 June 1983	11	84	45	1		
198	135	136	18 June 1983	12	86	48	1		
198	135	136	19 June 1983	13	87	47	1		
198	135	136	24 June 1983	14	92	48	1		
198	135	136	28 June 1983	15	96	46	1		

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
198	135	136	2 July 1983	16	99	47	1		
199	138	139	22 April 1982	1	33	70	1	2	3.4
199	138	139	17 July 1982	2	57	71	1	2	
199	138	139	13 June 1983	3	81	72	1	2	
201	140	141	2 May 1982	1	37	38	1	1	2.7
202	143	144	3 May 1982	1	38	72	1	3	5.2
202	143	144	4 May 1982	2	39	71	1	3	
202	143	144	15 June 1983	3	83	71	1	3	
202	143	144	3 July 1983	4	100	75	1	3	
203	145	146	3 May 1982	1	38	64	1	1	3.2
203	145	146	2 August 1982	2	68	19	1	2	
203	145	252	18 April 1983	3	89	19	1	2	3.6
203	266	252	7 June 1983	4	98	8	1	2	3.6
204	68	69	12 May 1982	1	42	5	2	1	3.2
204	68	69	18 July 1982	2	58	25	2	1	
204	68	69	5 April 1983	3	83	9	2	2	
205	70	71	12 May 1982	1	42	42	2	3	3.6
206	72	73	12 May 1982	1	42	51	2	1	2.3
206	72	73	13 June 1983	2	81	48	2	2	
206	72	73	15 June 1983	3	83	44	2	2	
207	74	75	13 May 1982	1	43	3	2	2	2.7
208	84	85	13 May 1982	1	43	49	2	1	3.0
209	147	148	15 May 1982	1	45	7	1	3	4.5
209	147	148	4 April 1983	2	82	1	1	3	
210	86	87	15 May 1982	1	45	17	2	2	4.1

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
210	86	87	28 May 1982	2	54	16	2	2	
210	86	87	30 July 1982	3	65	14	2	2	
210	86	87	17 April 1983	4	88	16	2	2	
210	86	87	6 June 1983	5	97	16	2	2	2.7
210	86	87	9 June 1983	6	100	16	2	2	
211	89	88	17 May 1982	1	47	16	2	3	2.3
212	151	152	17 May 1982	1	47	56	1	1	2.7
212	151	152	20 May 1982	2	50	17	1	1	
212	151	152	13 July 1982	3	53	77	1	2	3.6
212	151	152	13 June 1983	4	81	77	1	2	
212	151	152	23 June 1983	5	91	78	1	2	
213	149	150	17 May 1982	1	47	53	1	2	4.1
213	149	150	20 May 1982	2	50	51	1	2	
213	149	150	5 June 1982	3	58	51	1	2	
213	149	150	17 August 1982	4	68	17	1	2	
213	149	150	24 August 1982	5	75	51	1	2	
213	149	150	18 June 1983	6	86	51	1		
213	149	150	26 June 1983	7	94	51	1		
214	153	154	18 May 1982	1	48	16	1	3	4.1
214	153	154	21 May 1982	2	51	16	1	3	
214	153	154	27 July 1982	3	62	17	1	3	
214	153	154	30 July 1982	4	65	18	1	3	
214	153	154	31 July 1982	5	66	16	1	3	
214	153	154	2 August 1982	6	68	16	1	3	
214	153	154	18 August 1982	7	70	17	1	3	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
214	153	154	19 August 1982	8	71	16	1	3	
214	153	154	22 August 1982	9	74	16	1	3	
214	153	154	24 August 1982	10	76	16	1	3	
214	153	154	1 September 1982	11	80	14	1		
214	153	154	5 April 1983	12	83	16	1		
214	153	154	11 April 1983	13	85	16	1		
214	153	154	16 April 1983	14	87	16	1		
214	153	154	1 May 1983	15	91	14	1		
214	153	154	2 May 1983	16	92	17	1		
215	90	91	19 May 1982	1	49	9	2	2	3.4
216	155	156	19 May 1982	1	49	43	1	1	3.0
216	155	156	14 June 1983	2	82	46	1	2	
217	92	93	21 May 1982	1	51	12	2	1	2.5
217	92	93	27 May 1982	2	53	14		1	
217	92	93	30 July 1982	3	65	13	2	1	
217	92	93	31 July 1982	4	66	13	2	1	
217	92	93	2 August 1982	5	68	12	2	1	
217	92	93	18 August 1982	6	70	13	2	1	
217	92	93	22 August 1982	7	74	12	2	1	
217	92	93	1 September 1982	8	80	12	2	2	
218	94	95	22 May 1982	1	52	47	2	4	3.6
218	94	95	30 July 1982	2	61	48	2	4	
218	94	95	18 June 1983	3	86	47	2		
219	157	158	27 May 1982	1	53	6	1	4	4.5
219	157	158	18 August 1982	2	70	9	1	4	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
219	157	158	4 April 1983	3	82	6	1		
220	159	160	27 May 1982	1	53	55	1	2	3.4
221	96	97	29 May 1982	1	55	20	2	2	3.6
221	96	97	15 July 1982	2	55	29	2	2	3.2
221	96	97	28 July 1982	3	63	20	2	2	
221	96	97	30 September 1982	4	69	29	2	2	
222	98	99	30 May 1982	1	56	60	2	5	3.4
222	98	99	16 June 1982	2	43	61	2	5	
222	98	99	17 July 1982	3	57	63	2		
222	98	99	31 July 1982	4	62	59	2	5	
223	162	163	30 May 1982	1	56	54	1	4	4.8
223	162	163	14 June 1982	2	41	79	1	4	
223	162	163	19 July 1982	3	59	77	1	4	
223	162	163	26 June 1983	4	94	78	1		
223	162	163	1 July 1983	5	98	55	1		
224	164	165	30 May 1982	1	56	10	1	1	2.3
225	125	126	5 June 1982	1	58	42	2	4	3.2
225	125	126	14 June 1983	2	82	43	2	4	
226	128	127	5 June 1982	1	58	58	2	3	3.4
226	183	184	14 May 1983	3	93	19	2	2	3.2
227	129	130	5 June 1982	1	58	50	2	2	2.7
228	131	132	6 June 1982	1	59	46	2	4	3.4
228	131	132	25 August 1982	2	76	46	2	4	
228	131	132	16 May 1983	3	95	39	2	4	3.2
228	131	132	29 June 1983	4	97	46	2	4	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
228	131	132	1 July 1983	5	98	46	2	4	
229	166	167	12 June 1982	1	42	31	1	2	3.0
229	166	167	30 April 1983	2	90	18	1	2	
230	133	134	12 June 1982	1	42	29	2	1	2.7
230	133	134	20 July 1982	2	60	29	2	1	
231	135	136	12 June 1982	1	42	32	2	1	2.5
231	135	136	8 July 1982	2	50	7	2	1	
231	135	136	10 September 1982	3	65	32	2	1	
231	135	136	16 December 1982	4	78	32	2	1	
231	135	136	18 April 1983	5	89	32	2	2	
231	220	221	15 May 1983	6	94	32	2	2	3.2
232	138	137	12 June 1982	1	42	34	2	1	2.3
232	138	137	17 July 1982	2	57	34	2	1	
232	138	137	3 April 1983	3	81	34	2	2	
232	228	229	6 June 1983	4	97	34	2	2	2.7
233	139	140	12 June 1982	1	42	40	2	1	2.5
233	139	140	16 May 1983	2	95	40	2	2	3.2
234	141	142	13 June 1982	1	43	37	2	1	2.3
235	143	144	13 June 1982	1	43	38	2	3	3.6
235	143	144	18 July 1982	2	58	38	2	3	2.7
235	143	144	7 June 1983	3	98	38	2		
236	145	146	14 June 1982	1	41	66	2	1	3.6
236	145	146	16 June 1982	2	43	66	2	1	
236	145	146	16 June 1983	3	84	66	2	2	
236	145	146	18 June 1983	4	86	66	2	2	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
236	145	146	21 June 1983	5	89	66	2	2	
237	147	148	14 June 1982	1	44	27	2	3	3.2
237	147	148	25 June 1982	2	46	27	2	3	
237	147	148	15 July 1982	3	55	26	2	3	
238	168	169	15 June 1982	1	45	40	1	3	4.1
238	168	169	16 June 1983	2	84	62	1	3	
239	149	150	25 June 1982	1	46	34	2	2	3.0
240	151	152	26 June 1982	1	47	34	2	2	3.4
241	153	154	4 July 1982	1	46	64	2	2	3.4
241	153	154	18 June 1983	2	86	64	2	2	
242	173	174	8 July 1982	1	50	69	1	2	6.1
243	157	158	9 July 1982	1	51	25	2	2	3.6
244	155	156	9 July 1982	1	51	21	2	3	2.7
245	175	176	9 July 1982	1	51	24	1	1	3.2
245	183	176	14 July 1982	2	54	24	1	1	2.7
245	183	176	16 April 1983	3	87	34	1	2	
245	289	290	17 June 1983	4	85	65	1	2	3.2
245	289	290	20 June 1983	5	88	62	1	2	
246	179	180	10 July 1982	1	52	64	1	4	4.5
247	159	160	10 July 1982	1	52	31	2	2	3.2
248	177	178	10 July 1982	1	52	65	1	2	4.5
248	177	178	13 June 1983	2	81	66	1	2	
249	161	162	10 July 1982	1	52	67	2	2	3.4
249	161	162	16 June 1983	2	84	67	2	2	
249	161	162	3 July 1983	3	100	64	1	2	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
250	181	182	13 July 1982	1	53	72	1	2	5.2
250	181	182	8 September 1982	2	63	75	1	2	
250	181	182	1 October 1982	3	70	75	1	2	
250	181	182	19 June 1983	4	87	75	1		
250	181	182	24 June 1983	5	92	71	1		
251	163	164	14 July 1982	1	54	61	2	3	3.6
252	184	185	15 July 1982	1	55	69	1	2	4.1
252	184	185	20 July 1982	2	60	69	1	2	
253	165	166	18 July 1982	1	58	28	2	2	2.7
254	167	168	19 July 1982	1	59	36	2	5	3.2
255	169	170	19 July 1982	1	59	40	2	2	3.2
255	169	170	11 September 1982	2	66	40	2	2	
255	169	170	18 April 1983	3	89	40	2		
256	171	172	20 July 1982	1	60	68	2	3	3.6
256	171	172	3 July 1983	2	100	67	2	3	3.6
257	173	174	26 July 1982	1	61	4	2	2	3.4
258	175	176	28 July 1982	1	63	18	2	3	3.2
258	175	176	30 August 1982	2	78	16	2	3	
258	175	176	8 June 1983	3	99	17	2	3	
259	177	178	29 July 1982	1	64	4	2	4	3.2
260	187	188	30 July 1982	1	65	1	1	1	1.4
260	187	188	22 June 1983	2	90	42	1	1	
261	190	191	31 July 1982	1	62	58	1	1	4.1
262	192	193	1 August 1982	1	67	13	1	1	3.2
262	192	193	14 May 1983	2	93	12	1	1	

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
263	179	180	2 August 1982	1	64	56	2	1	0.9
263	179	180	22 June 1983	2	90	57	2	1	
263	179	180	25 June 1983	3	93	56	2	1	
264	194	195	3 August 1982	1	65	60	1	1	3.2
265	181	182	14 August 1982	1	67	55	2	1	2.7
265	181	182	10 September 1982	2	65	79	2	2	
266	183	184	17 August 1982	1	69	20	2	1	2.7
266	183	184	4 April 1983	2	82	19	2	2	
267	197	198	17 August 1982	1	68	59	1	2	2.7
267	197	198	24 June 1983	2	92	60	1	2	
268	185	186	17 August 1982	1	68	47	2	5	2.7
268	185	186	18 September 1982	2	68	39	2	5	
268	185	186	18 June 1983	3	86	46	2	5	
269	187	188	17 August 1982	1	68	54	2	2	2.7
269	187	188	26 June 1983	2	94	55	2	2	
270	189	190	18 August 1982	1	70	7	2	1	1.4
271	199	200	18 August 1982	1	69	56	1	5	4.5
271	199		12 October 1982	2	76	76	1	5	
272	201	202	23 August 1982	1	74	60	1	1	4.5
272	201	202	26 June 1983	2	94	75	1	2	
273	203	204	6 September 1982	1	61	38	1	2	3.6
274	191	192	6 September 1982	1	61	36	2	3	2.7
275	205	206	7 September 1982	1	62	28	1	1	1.4
276	193	194	7 September 1982	1	62	28	2	1	1.4
277	207	208	8 September 1982	1	63	66	1	1	1.8

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
277	207	208	3 October 1982	2	72	66	1	1	
278	209	210	9 September 1982	1	64	31	1	1	3.6
279	211	212	11 September 1982	1	66	34	1	2	4.1
279	249	212	11 April 1983	2	85	40	1	2	4.1
280	213	214	17 September 1982	1	67	31	1	1	2.3
280	213	214	15 May 1983	2	94	31	1	1	
281	215	216	17 September 1982	1	67	64	1	2	3.6
282	217	218	18 September 1982	1	68	25	1	1	1.4
282	217	218	16 December 1982	2	78	25	1	1	
282	217	218	15 May 1983	3	94	25	1	1	
283	219	220	30 September 1982	1	69	80	1	1	2.7
284	195	196	1 October 1982	1	70	66	2	1	1.4
284	195	196	4 October 1982	2	73	66	2	1	
284	195	196	10 October 1982	3	74	70	1	1	
284	194	195	21 June 1983	4	89	68	2	1	
285	221	222	1 October 1982	1	70	66	1	1	1.4
285	221	222	16 December 1982	2	78	66	1	1	
286	223	224	2 October 1982	1	71	36	1	1	1.8
287	225	226	2 October 1982	1	71	63	1	1	2.3
288	197	198	3 October 1982	1	71	21	2	2	3.6
288	197	198	1 May 1983	2	91	21	2	2	
288	197	198	7 June 1983	3	98	21	2	2	
290	201	202	3 October 1982	1	72	72	2	5	3.6
291	199	200	3 October 1982	1	72	73	2	2	3.6
292	229	230	4 October 1982	1	73	78	1	1	1.8

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
293	231	232	6 October 1982	1	75	33	1	1	1.8
294	233	234	10 October 1982	1	76	25	1	1	1.8
294	233	234	3 April 1983	2	81	24	1	1	
294	233	234	1 May 1983	3	91	24	1	1	
294	233	234	15 May 1983	4	94	24	1	1	
295	203	204	10 October 1982	1	76	36	2	2	4.1
296	235	236	11 October 1982	1	75	66	1	1	2.7
297	205	206	12 October 1982	1	76	70	2	2	3.2
298	237	238	16 December 1982	1	78	22	1	1	2.3
299	207	208	16 December 1982	1	78	72	2	2	3.2
301	209	210	21 December 1982	1	79	32	2	3	4.5
302	239	240	22 December 1982	1	80	65	1	2	5.9
303	211	212	3 April 1983	1	81	30	2	2	2.7
304	213	214	5 April 1983	1	83	25	2	1	1.8
305	243	244	5 April 1983	1	83	36	1	3	3.2
306	245	246	10 April 1983	1	84	32	1	2	3.2
307	247	248	10 April 1983	1	84	13	1	2	3.6
307	247	248	5 June 1983	2	96	13	1	2	
307	247	248	9 June 1983	3	100	12	1	2	3.6
308	250	251	12 April 1984	1	84	1	1	2	5.0
309	256	257	1 May 1983	1	91	3	1	3	4.5
309	256	257	15 May 1983	2	94	5	1	3	
310	216	217	2 May 1983	1	92	27	2	1	1.8
311	218	219	14 May 1983	1	93	16	2	2	3.2
312	258	259	16 May 1983	1	95	33	1	2	3.2

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
313	260	261	16 May 1983	1	95	29	1	1	2.3
314	262	263	16 May 1983	1	95	24	1	1	2.3
314	262	263	7 June 1983	2	98	24	1	1	
315	264	265	16 May 1983	1	95	6	1	2	4.1
316	222	223	5 June 1983	1	96	38	2	1	2.3
317	224	225	5 June 1983	1	96	18	2	1	2.7
318	226	227	5 June 1983	1	96	10	2	2	3.2
319	230	231	6 June 1983	1	97	37	2	1	2.3
320	232	233	6 June 1983	1	97	33	2	1	2.3
321	268	267	7 June 1983	1	98	22	1	1	2.7
322	269	270	7 June 1983	1	98	31	1	1	4.1
323	234	235	7 June 1983	1	98	9	2	2	2.7
324	273	274	13 June 1983	1	81	45	1	3	4.1
325	275	276	13 June 1983	1	81	79	1	1	3.6
325	275	276	21 June 1983	2	89	77	1	1	
326	277	278	14 June 1983	1	82	69	1	1	3.6
327	279	280	14 June 1983	1	82	41	1	1	3.6
328	242	243	14 June 1983	1	82	66	2	5	3.2
328	242	243	21 June 1983	2	89	70	2	5	
329	240	241	14 June 1983	1	82	70	2	2	3.2
330	281	282	15 June 1983	1	83	72	1	1	3.2
331	244	245	15 June 1983	1	83	49	2	2	2.7
332	285	286	16 June 1983	1	84	75	1	1	2.7
332	285	286	17 June 1983	2	85	75	1	1	
332	296	297	20 June 1983	2	88	75	1	1	2.3

Table 14. Continued

ID Number	Right Tag Number	Left Tag Number	Capture Date	Number of Captures	Sample Period	Capture Site	Sex	Age	Weight
332	296	297	21 June 1983	3	89	75	1	1	
332	296	297	22 June 1983	4	90	75	1	1	
333	287	288	17 June 1983	1	85	51	1	2	2.7
333	287	288	22 June 1983	2	90	50	1	2	
333	287	288	25 June 1983	3	93	44	1	2	
334	246	247	18 June 1983	1	86	80	2	1	2.7
335	248	249	18 June 1983	1	86	60	2	2	2.7
336	250	251	18 June 1983	1	86	73	2	5	2.7
337	252	253	19 June 1983	1	87	54	2	2	2.7
338	254	255	19 June 1983	1	87	69	2	1	3.6
339	291	292	19 June 1983	1	87	49	1	1	2.7
340	256	257	20 June 1983	1	88	52	2	2	2.7
341	294	295	20 June 1983	1	88	80	1	1	2.7
342	298	299	21 June 1983	1	89	69	1	2	4.1
343	263	264	22 June 1983	1	90	76	2	2	2.7
344	300	301	23 June 1983	1	91	64	1	2	3.6
345	302	303	23 June 1983	1	91	68	1	2	3.2
346	304	305	24 June 1983	1	92	59	1	1	2.7
347	306	307	25 June 1983	1	93	53	1	2	3.6
348	310	311	27 June 1983	1	95	69	1	1	4.1
349	258	259	27 June 1983	1	96	65	2	1	2.7
350	312	313	2 July 1983	1	99	42	1	2	2.7

APPENDIX B

Table 15. Total captures of non-target mammals trapped on CSMMA study areas, 1981-83.

Opossum	Groundhog	Gray Fox	Red Fox	Dog ^a	House Cat ^a	Striped Skunk	Gray Squirrel	Cottontail Rabbit
480 ^b (272) ^c	125 ^b (34) ^c	6	5	21	10	38 ^b	7	16 ^b

^aAnimals removed from the management area.

^bTotals may include recaptures. However, opossum capture data from July 1982 to July 1983 consists largely of individual captures because permanent marking was initiated in July 1982.

^cKnown recaptures in parentheses.

APPENDIX C

Table 16. Scent-station visitation rates (overall measure) for raccoons and other mammals from 1396 operable stations on CSWMA, 1981-83.

Mammal	Total # Visits, N	Visitation Rate, % (N/Total Stations)
Raccoon	70	5.01
Opossum	107	7.66
Gray fox	49	3.51
Red fox	10	0.72
Both foxes ^a	60	4.30
Dog	15	1.10
Cat	3	0.21
Striped skunk	8	0.57
Mink	1	0.07
Cottontail rabbit	75	5.37
White-tailed deer	25	1.79
Woodchuck	16	1.15
Gray squirrel	37	2.65
Totals: 13 species	476	Mean = 2.6

^aBoth foxes combined, plus an unidentified fox.

VITA

Ben G. Nottingham, Jr., son of Mr. and Mrs. Ben Nottingham, was born in Lakeland, Florida, on July 21, 1954. He attended Needham Broughton High School in Raleigh, North Carolina, graduating in 1972. In December 1977, he graduated with high honors from North Carolina State University with a Bachelor of Science in Wildlife Biology. From 1978 to 1981, he worked in temporary appointments with the National Park Service and U.S. Fish and Wildlife Service. In October of 1981, he entered the graduate program in Forestry, Wildlife, and Fisheries, The University of Tennessee, Knoxville. In 1984, he participated in a jaguar ecology study in Belize, Central America, sponsored by the New York Zoological Society. He received a Master of Science in Wildlife and Fisheries Science in June 1985.